UNITED STATES ATOMIC ENERGY COMMISSION

ALI-8

QUALITATIVE SPECIFICATIONS FOR ANIMAL LABORATORIES FOR EXPERIMENTAL WORK WITH RADIOACTIVE MATERIALS TO BROOKHAVEN NATIONAL LABORATORY

December 8, 1948

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INTRODUCTION

The purpose of this report is to furnish information upon which designs for animal laboratories employing radioactive materials may be based.

The importance to man of an extensive and thorough investigation of the biological and physiological effects of radioactive materials cannot be overestimated, and the most practical approach to the establishment of the required knowledge is through the medium of animal experimentation. The control of disease, the effects of ingestion and inhalation of radioactive materials, the development of mutations, the protection of scientists and industrial workers, and the uses of tracer technology illustrate a few of the opportunities which invite extensive research.

Appreciation of the necessity for first-class facilities can be gained from an appraisal of the difficulties which beset experimental animal laboratories.

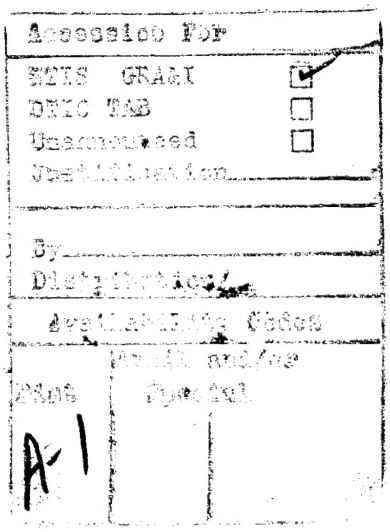
Animals are subject to numerous diseases, infections, physiological changes, and epidemics which result from insufficient attention to environmental effects. The history of experimental work with animals is replete with large losses of animals, often during the course of important experimental programs, and not infrequently entire colonies on long-term chronic studies have been wiped out. Significant losses of investment in experiments and costly animals resulted, and larger and more expensive animal populations were required to ensure significant numbers of animals at the end of experiments to validate conclusions.

Proper environmental facilities will promote the growth and health of animals, will largely eliminate serious infections and epidemics, will

eliminate many variables, increase assurance of the success of experimental projects, reduce or eliminate the necessity of repeating experiments, and effect significant economies in the overall cost of operations.

All of these difficulties will exist at Brookhaven plus the complications introduced by radioactive materials. Precautions must be taken to prevent the breathing or ingestion of radioactivity by personnel. Absorption through the skin or in lacerations, or by the effects of perspiration, must be minimized and the effects of direct exposure to rays must be prevented. Radiation side effects on animals and hazards to personnel must be minimized by precautionary measures provided for in the construction, the equipment, and the techniques of operation.

Proper engineering of the animal laboratories can contribute as much as any other factor to promote more precise results, with fewer animals, in less space, with less danger, and at minimum cost.



THE ASSIGNMENT

Objective

When the proposed laboratories for radioactive experiments with animals were under consideration at Brookhaven, it was decided that basic information for design purposes would be beneficial for them and for other institutions desiring such facilities. No adequate source of information was found to exist, so Arthur D. Little, Inc., was authorized to assemble and evaluate available information pertinent to the construction of animal laboratories, including recommendations as to layout, materials of construction, techniques of operation, and precautionary measures. The preparation of designs and detailed constructions plans are not included. These four major aspects are covered in separate sections of this report.

The animal population in the completed project will be adequate for the study of the biological consequences of the ingestion and inhalation of radioactive isotopes. Since much of this research is of a long-term nature, it is important that the projects be started in facilities whose design has been the subject of careful thought and analysis. For these reasons the laboratory will serve as a model for similar facilities, which will be built by other groups, so that perfection of essential detail in the development of the laboratories is of the utmost importance.

General Requirements

Certain definitions and understandings have been agreed upon, as follows:

The information assembled shall apply to animal laboratories to be used for studies involving the effects of radioactive isotopes or where

radioactive isotopes facilitate other types of studies.

For the purposes of this report, it is understood that the term "animal laboratories" includes all facilities pertinent to the receiving, quarantining, breeding, housing, and maintenance of animals. Laboratories for biological and pathological examination or other experimental work, or office and employee facilities, are to be considered separately.

The maximum level of radioactivity specified in the original contract as "the ten millicurie level" is construed to mean that within the zone where such work is being conducted, a standard type counter will show not more than 10 millicuries of a radioactive isotope to be present in any one animal or at any one location in a diet preparation or decontamination area. For the purposes of this report, such isotopes will be limited to beta emitters of radiation intensity not greater than P_{32}.

The laboratories shall be designed to provide maximum adaptability to accommodate numerous and varied experiments, including long-term chronic studies.

Provisions shall be made for maximum protection of the staff and animals.

Means for disposing of waste materials or by-products within the animal colony areas are required but ultimate disposal problems are under consideration.

The terms layout, materials of construction, techniques of operation, and precautions apply only to the "animal laboratories" and the activities carried out in them.

The animal colonies shall be operated on an infection-free basis to the greatest extent possible.

Experimental animals can be maintained satisfactorily with a minimum of exercise, which permits the use of minimum cage sizes and floor areas.

PROCEDURE

Our procedure for assembly and evaluating available pertinent information has consisted of visiting and studying animal laboratories in the United States and Canada, as listed in Appendix B. Among the establishments were pharmaceutical houses, breeding and stock colonies, universities, Federal Agencies, endowed institutions, and A.E.C. laboratories.

A list of pertinent literature is given in Appendix C for reference. This information has been analyzed and evaluated and its integration with the work of our own staff forms the basis of the recommendations contained in this report and summarized as follows.

CONCLUSIONS

I. Proper environmental conditions for the animals can contribute as much as any other factor to the success of experimental programs with minimum animal populations, conservation of space, insurance against loss of time and animals, and minimum operating cost. These can be effected by incorporating in the design provisions for the segregation of areas, for air conditioning, uniform lighting and the control of noise and vermin.

II. The segregation of numerous areas of activity is important to facilitate control of environmental effects, to prevent the spread of infections or epidemics, to separate species and strains of animals and to promote experimental programs and operating efficiency.

III. A master plan should be created for governing the design and construction of buildings and equipment from the initial undertaking through successive steps to the ultimate development of the laboratory facilities. Careful attention should be given to the standardization of equipment and buildings. Adaptability and flexibility of facilities will be accomplished thereby, and significant economies in construction and operating costs, and the cost of additions will be effected.

IV. Economical single-story buildings without basements will meet all of the requirements of animal laboratories, and the omission of exterior windows will facilitate control of environmental conditions. All of the buildings can be of standard construction with added provisions for protection in radioactive areas. No special or costly buildings will be required.

V. Equipment such as cages, racks, feeding and waste collecting containers should be standardized and interchangeable as far as possible within but not between radioactive and non-radioactive areas.

VI. The establishment of breeding colonies for small animals is advisable for extensive laboratories which require substantial regular supplies of animals of uniform characteristics. The breeding colonies should be operated on an infection-free basis to ensure quality and reduction of breeding costs by virtue of increased growth rates per unit of time and diet. An assured supply of animals of uniform characteristics and high quality and a reduction in quarantine facilities are the principal benefits.

VII. Facilities, procedures, and operating techniques which permit convenient operation and present minimum radiation hazards have not been provided to date by any of the institutions we have contacted. New engineering specifications and designs must be developed to meet these requirements.

VIII. The design of radioactive animal quarters must combine proper facilities for maintaining the animals with provisions for protecting them from radiation exposure, and suitable protection for personnel. The design should facilitate maintenance of these conditions and effective decontamination procedures.

IX. The principal hazards in radioactive animal colonies will consist of dust in the air from diets, hair shed by animals, dried-out fecal matter, bedding, and housekeeping. In diet preparation areas radiation hazards will be added. In equipment cleaning and decontamination areas radiation hazards will predominate. These hazards can be minimized by providing proper facilities and by the development and supervision of operating techniques by properly qualified personnel.

X. In radioactive areas, dry construction involving multilayers of radiation protection are recommended for all surfaces where contamination can occur. This protection can consist of strippable films or materials which can be safely and easily removed and replaced.

XI. Equipment for use in radioactive areas should be designed for safe and effective cleaning and decontamination. The cages and food and water dispensers should present smooth surfaces with a minimum of joints, folds, or cracks where dirt, dust or radioactivity can accumulate. The racks, trays, and service carts should also present smooth surfaces and can be covered with strippable films to facilitate decontamination.

XII. As radiation intensity levels increase, more expensive construction, shielding, and operational procedures are required. Economies of construction and operation can be effected by providing separate facilities for work at low and high intensity levels.

XIII. Our recommendations for materials for construction and equipment are based on current knowledge and developments. A program for further testing and evaluating materials is recommended in the interest of determining in this rapidly developing field those which will give optimum results at minimum cost.

I. LAYOUT

Functional Diagram

A functional diagram of the areas of activity required for a model animal laboratory designed for experimental work with radioactive materials is shown in Figure I. It indicates the variety, the relationships, and the segregation of the major areas of activity which should be provided. The principle of segregation can be accomplished by means of separate buildings, by walls and partitions within buildings, or by a combination of both, depending upon the number and variety of the animal population and the experimental programs of the laboratories.

Master Plan

The creation of a master plan for governing the physical development of the proposed animal laboratories is essential. Such a plan should visualize the probable number and size of the ultimate development in buildings and equipment, so that, regardless of the scope of the original undertaking, or of subsequent additions, an efficient layout and an orderly construction program will be ensured at minimum overall cost.

The plan should be integrated from the quantitative and the functional requirements of the experimental laboratories and should comprise the controlling principles of layout, and the general specifications and drawings necessary for guiding each step of the design and construction program.

Buildings

General Provisions

Individual buildings should be vermin proof, fireproof, and comparatively airtight, both externally and internally. They should be readily adaptable to a great variety of experimental programs without

FUNCTIONAL DIAGRAM
TYPICAL ANIMAL LABORATORY

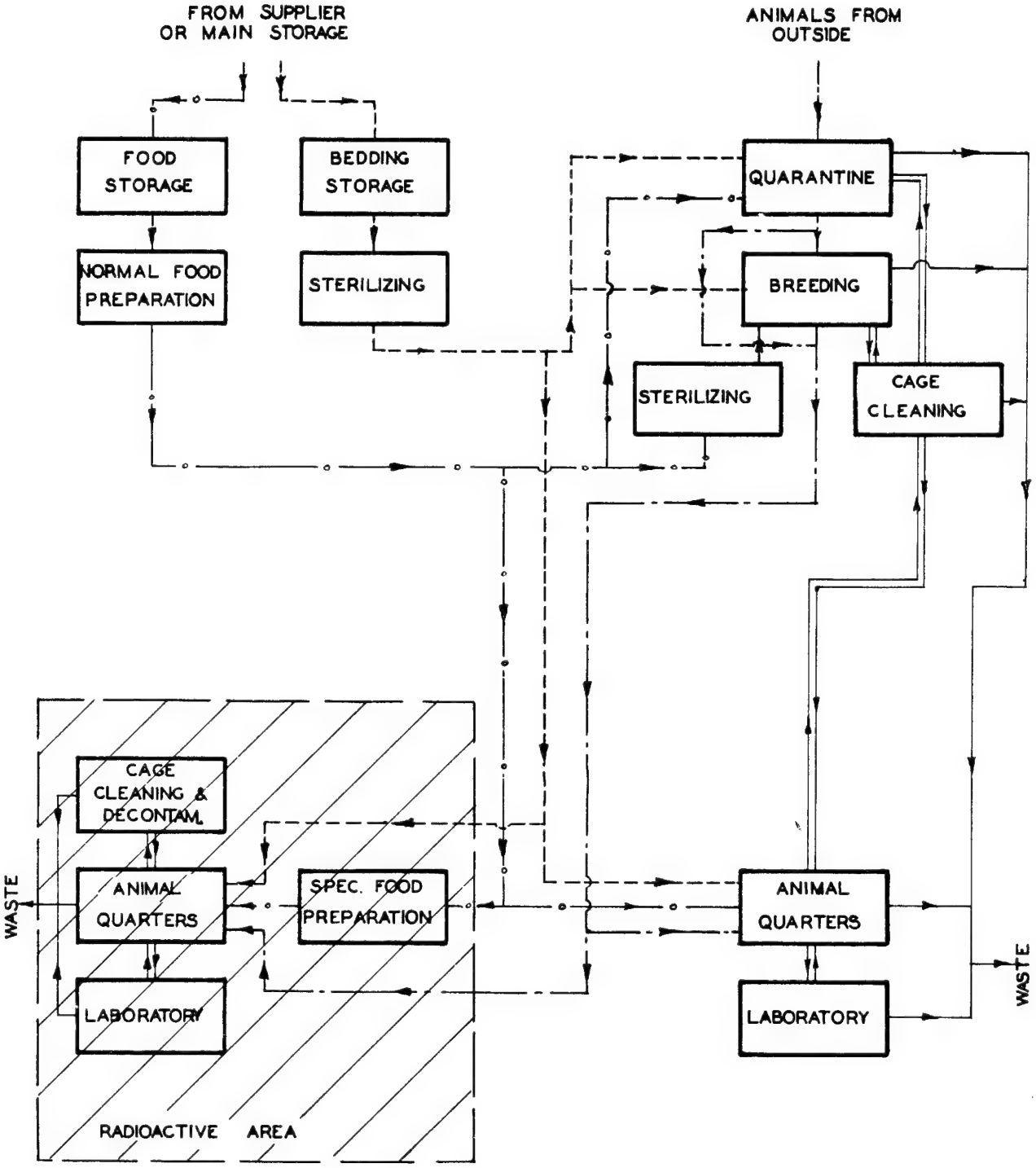


FIGURE 1.

compromising the operating efficiency of the laboratories and animal quarters.

Construction costs should be as low as possible, consistent with the high standards which are required for a model animal laboratory using radioactive materials. With this end in view, all of the buildings should be of a standard size, as far as possible.

Number Required

Determination of the number of buildings which are to be constructed at any given time will require an integration of both the quantitative and the qualitative requirements. It involves the numbers and varieties of animals and experimental facilities, provisions for segregation, special techniques, and protection, all of which are essential for successful operation. One properly designed building could house the activities of a small animal laboratory, but an extensive institution may require a number of single-purpose buildings.

Building Outlines

Single-story buildings without basements or windows are inherently suitable for animal laboratory purposes since the operations to be carried out in them are easily conducted on a single level. They are economical to construct, and additions or alterations to them can be effected with minimum disturbance and overall cost. A limited number of exterior windows may be desirable in some laboratory and office areas for psychological reasons.

Multi-story buildings can be utilized if ground area is limited or if space planning indicates that a more efficient overall

layout would result. Multi-story wings or ells for office and experimental laboratory purposes may well be justified because of savings in space and utilities costs.

Ease of converting buildings from one purpose to another will be reduced if both single- and multi-story construction is used. It therefore seems advisable to standardize on one-story units to obtain maximum adaptability at minimum cost.

Building Sizes

The size or overall dimensions of any individual building will depend upon current laboratory requirements and will be determined by multiples of a standard area or room plus corridors and access areas. A 20-foot by 30-foot room size has been indicated for general laboratory purposes and this same area will accommodate a majority of the animal quarter activities as will be demonstrated in a later section. The height from floor to ceiling should be approximately nine feet. By using a modular design, engineering and construction costs will be reduced to a minimum.

Building Interiors

Having in mind the special provisions which must be made in the design of animal laboratories, it appears that the building interiors must be subdivided into numerous segregated areas or rooms. It has already been indicated that areas of 20 feet by 30 feet will meet a majority of requirements and will promote low construction costs. These areas can be subdivided by means of movable partitions to form smaller rooms. Such uniformity and flexibility will permit changes in occupancy to be readily effected at reasonable cost.

A standardized interior arrangement for the laboratory buildings which would be economical to construct would consist of one row of 20-foot by 30-foot rooms on each side of an eight-foot wide corridor. The resulting building would be 48 feet wide by multiples of 30 feet in length.

An alternate but more expensive arrangement would provide a service corridor for each row of rooms in addition to a main corridor. All movement of animal colony personnel and materials would be confined to the service corridors and colony rooms and the main corridor would not be exposed to the effects of dust, dirt, or radioactivity.

Provision should be made to enable visitors to inspect the laboratories without permitting them to enter the rooms. This can be accomplished by installing windows in the corridor walls.

The capacity and the adaptability of the 20-foot by 30-foot room is illustrated in Figures 2, 3, 4, and 5, which show typical examples of the numbers, sizes, and arrangements of cages for commonly used animals, and how they fit into the base area and its subdivisions.

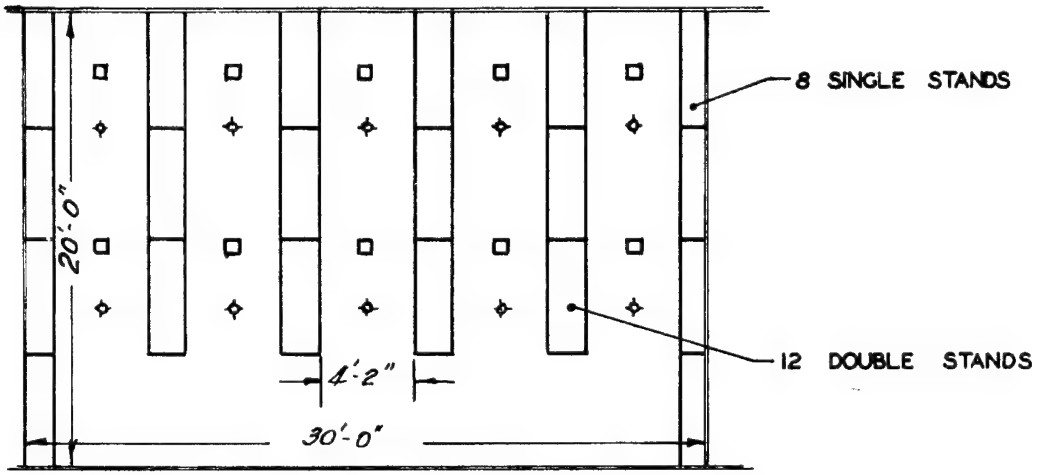
Rooms

General Requirements

For proper segregation of areas, the walls and partitions should be as nearly vermin proof, fire proof, and airtight as possible. Special entrances and exits will be required for the breeding colony and in the radioactive areas.

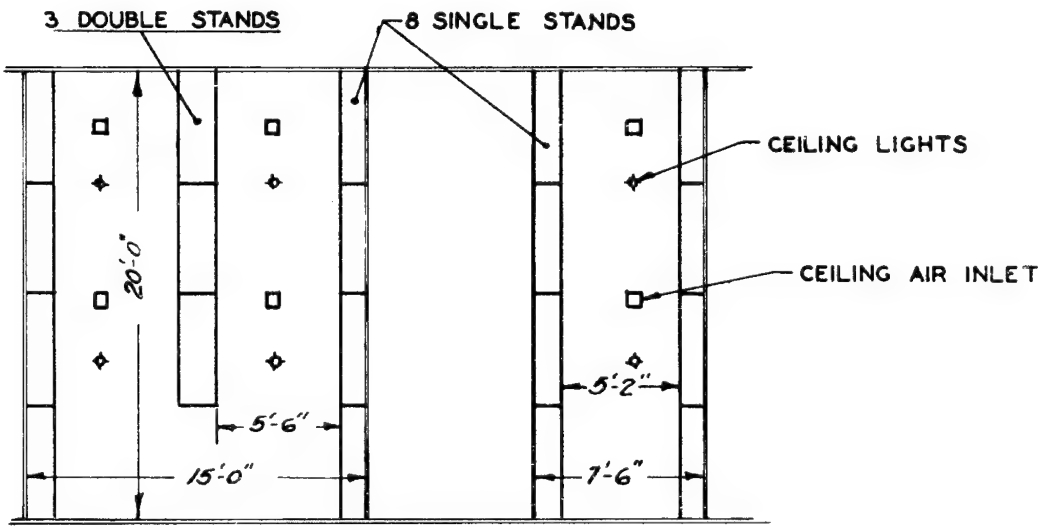
All surfaces should be smooth, having the minimum of projections, ledges, joints or cracks that are difficult to clean or where dust or vermin can collect. There should be no exposed piping, wiring or ducts,

TYPICAL ROOM ARRANGEMENTS FOR RATS AND MICE



20' X 30' ROOM

960 - 7"X 10"X 7" CAGES FOR RATS
2240 - 4"X 7"X 5" CAGES FOR MICE



15'X 20' ROOM

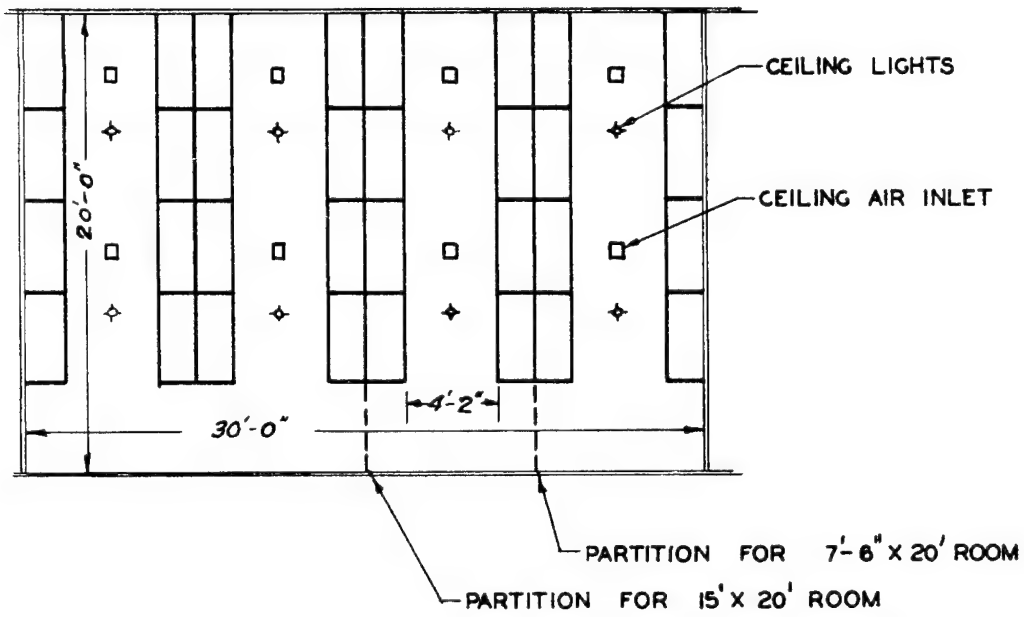
420 - 7"X 10"X 7" CAGES FOR RATS
980 - 4"X 7"X 5" CAGES FOR MICE

7'-6" X 20' ROOM

240 - 7"X 10"X 7" CAGES FOR RATS
560 - 4"X 7"X 5" CAGES FOR MICE

FIGURE 2

TYPICAL ROOM ARRANGEMENTS FOR RABBITS AND GUINEA PIGS



CAPACITIES

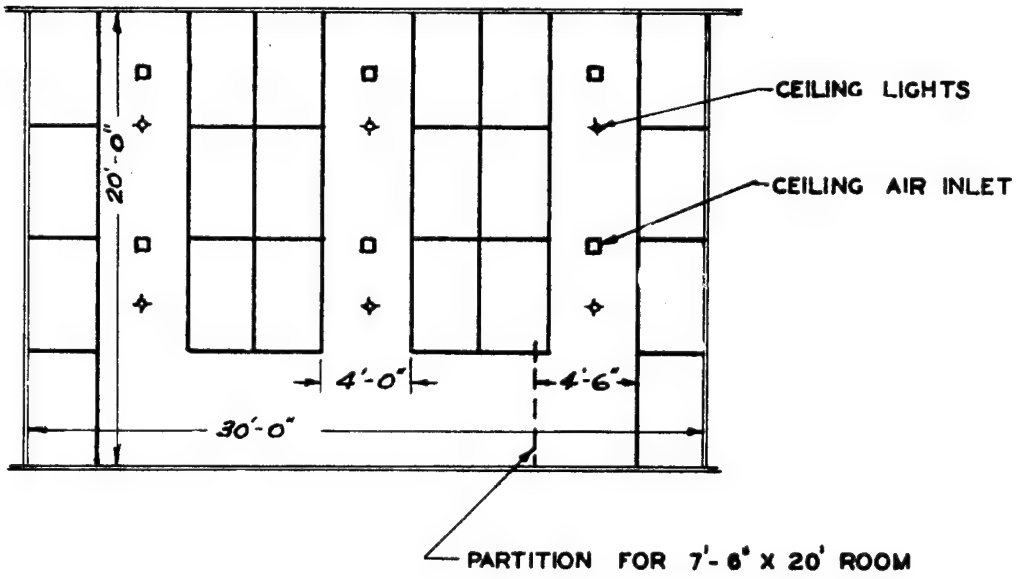
30' X 20' ROOM
- 32 SINGLE STANDS
- 256 - 22" X 20" X 15" CAGES
- 512 - 22" X 10" X 15" CAGES

15' X 20' ROOM
- 16 SINGLE STANDS
- 128 - 22" X 20" X 15" CAGES
- 256 - 22" X 10" X 15" CAGES

7'-6" X 20' ROOM
- 8 SINGLE STANDS
- 64 - 22" X 20" X 15" CAGES
- 128 - 22" X 10" X 15" CAGES

FIGURE 3

TYPICAL ROOM ARRANGEMENTS FOR SMALL DOGS AND MONKEYS



CAPACITIES

30' X 20' ROOM

20 SINGLE STANDS
80 - 26" X 36" X 26" CAGES

7'-6" X 20' ROOM

4 SINGLE STANDS
16 - 26" X 36" X 26" CAGES

FIGURE 4

TYPICAL LABORATORY ARRANGEMENT

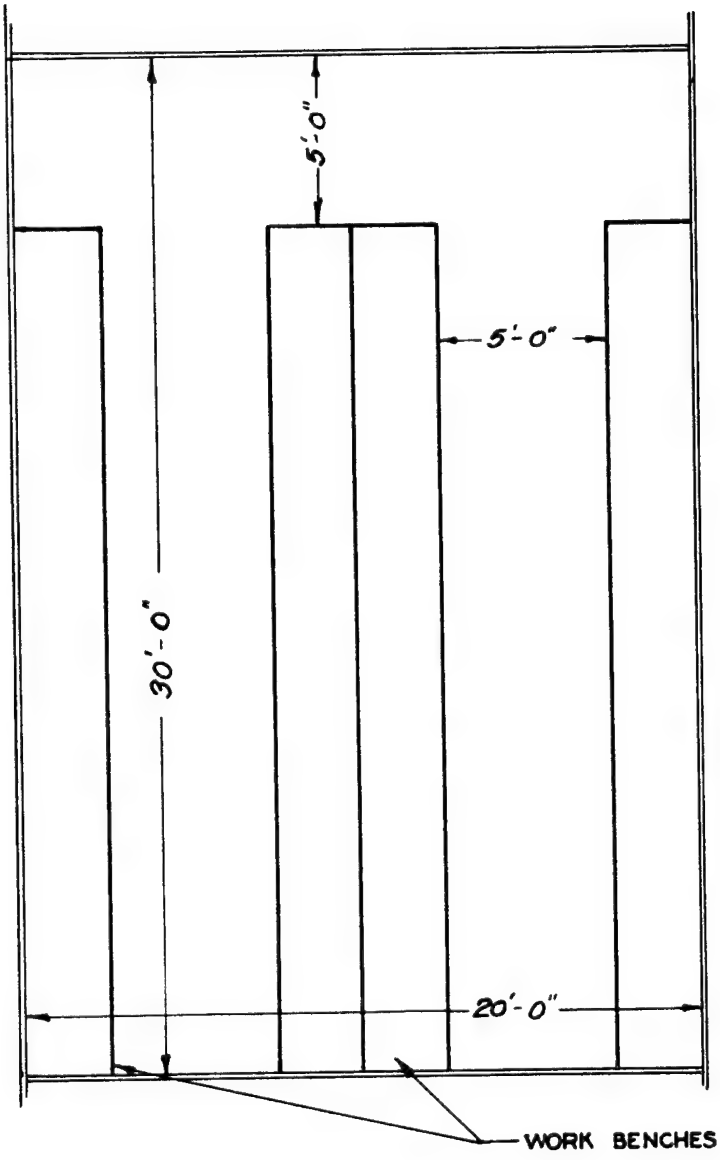


FIGURE 5

all of which can be located in an accessible space either over the ceilings or in a service tunnel. The lighting fixtures should be flush mounted, if possible.

Materials of construction are specified in a separate section of this report.

All rooms should be air conditioned in accordance with specifications contained in a separate section of this report entitled "Air Conditioning."

Floor drains should not be provided in animal rooms. They are difficult to maintain in a vermin free and sanitary condition and are difficult to repair in case of stoppages. Qualified personnel should be employed for floor cleaning, particularly in radioactive areas, and there should be no possibility of undesirable materials escaping from the colonies through drains.

Water should be available in food preparation or sterilization areas, not in animal rooms.

Rooms Containing No Radioactivity

Reference to the Functional Diagram, Figure 1, indicates in the non-radioactive section of the animal laboratory, ten major areas of activity, each of which must be segregated from the others.

Special mention should be made of the layout of the infection-free breeding areas. A single entrance and exit opening for personnel should be provided. This entrance should include facilities for personnel to remove street clothes, shower and dress in clothes worn only in the colony. A large steam sterilizer should be provided to serve as a lock connecting the colony room with the outside. This sterilizer must be

designed so that the doors to the colony room and the outside can never be open at the same time. All cages, racks, and service equipment entering the colony must do so through this sterilizer, being sterilized before admitting to the colony. Equipment must also be provided to sterilize bedding and diet components not made under conditions of pharmaceutical cleanliness. Such sterilizing equipment must be of special design due to the high insulating capacity of the materials to be treated. Details of equipment developed at The Lobund Laboratories of Notre Dame for this purpose should be obtained.

The same environmental conditions should be provided for quarantine areas as for the regular animal quarters.

Rooms Containing Radioactivity

The Functional Diagram, Figure 1, indicates four major areas where radioactive materials will be present and segregation will be required.

Radioactive "Levels"

In radioactive experimentation the hazards to personnel increase rapidly with increasing levels of radiation intensity. As these levels increase, more and more expensive types of construction are required for protection of personnel. Where possible, it will be desirable to provide quarters which can be used only up to certain maximum radiation intensities since they can be built more cheaply than quarters to be used at higher intensities. We visualize economies in construction of Brookhaven's proposed animal laboratories by providing at least three types of areas having increasing levels of radioactivity. These are defined as follows:

1. Areas where from 1 to 100 microcuries per rat will not be exceeded are designated as Number 1 areas.

2. Areas where .1 to 10 millicuries per rat will not be exceeded are designated as Number 2 areas.

3. Areas for special small scale experiments at higher levels of radioactivity are designated as Number 3 areas.

Colony Rooms

Rooms where experimental work with animals is conducted in accordance with the specifications for a Number 1 area should have floor, wall, ceiling, and equipment surfaces covered by easily removable coatings which can be scraped or washed off to effect decontamination.

Rooms containing experimental animals which are operated as Number 2 areas will require protective coatings and strippable films on the surfaces of floors, walls, ceilings, and equipment. Some shielding may be required to protect animals from side effects of radioactivity or their cages must be spaced.

Vertically adjustable screens to simulate hoods could be mounted in front of the cages to ensure a positive direction of air flow first to any individuals in the colony room then through the cages, and out. Figure 6 illustrates this. The optimum design for safety would call for the provision of hoods.

Small scale experiments involving radioactivities beyond the "levels" specified for this report are contemplated. Some of these experiments will be conducted in laboratories under hoods. Others can be undertaken in Number 2 area facilities spacing the animals at increased distances and using remote handling equipment.

Other experiments contemplated will require animals to live in radioactive atmospheres. To meet these circumstances the consensus of

DISTRIBUTION OF AIR IN TYPICAL RADIOACTIVE ROOM

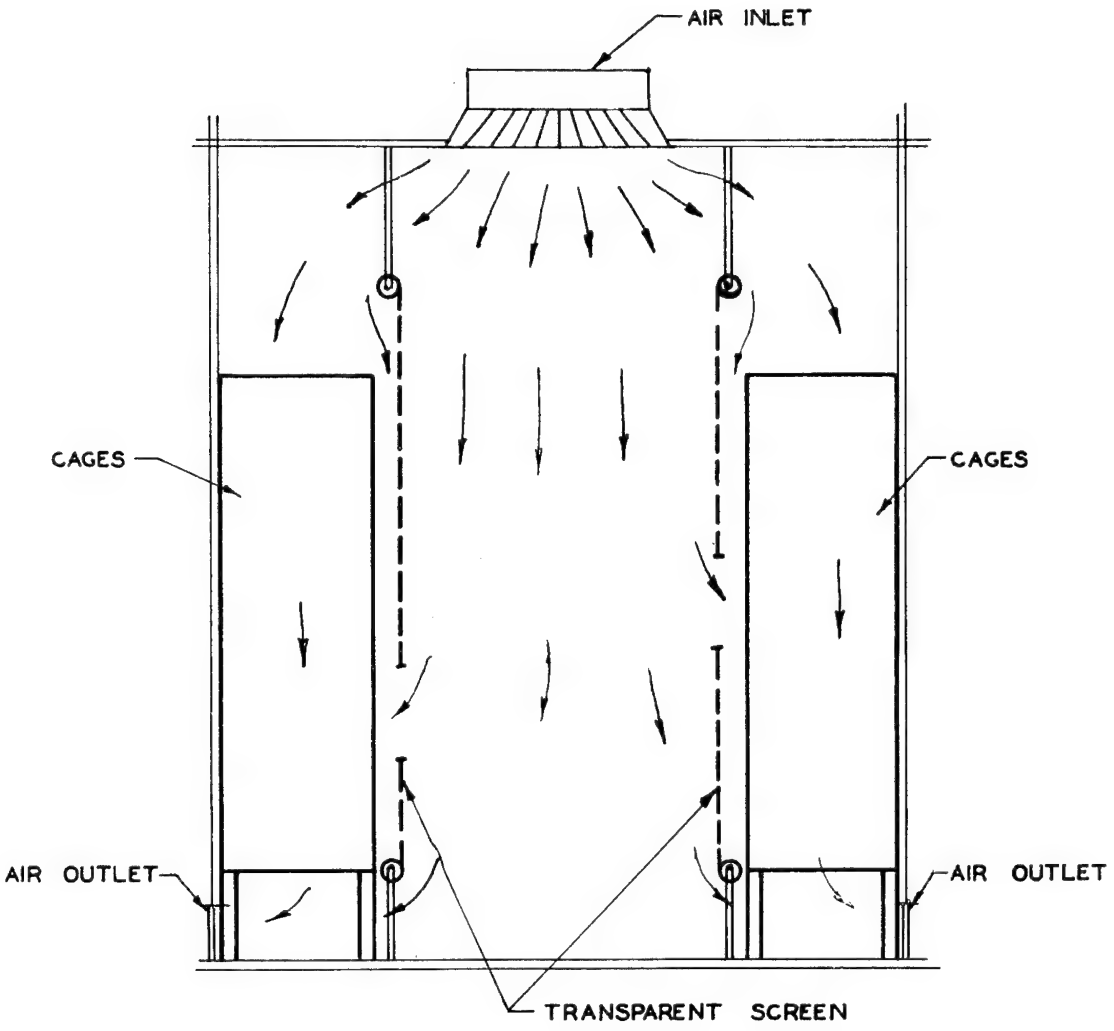


FIGURE 6

opinion favors housing the animals within an area which is large enough for personnel to work in rather than to confine the animals in small chambers and attempt to manipulate and care for them by complicated remote control methods. Supplied air masks should be worn. Protective clothing will be necessary unless it can be conclusively shown that gaseous materials are not absorbed through the skin.

Diet Kitchen

Rooms where diets and special foods containing radioactive isotopes are prepared are Number 2 areas. Hoods should be provided under which the introduction of isotopes into diets and filling and covering food containers should be done. Floors, walls, ceilings and equipment should be covered with protective coatings and strippable films for safety and effectiveness of decontamination.

Equipment Cleaning and Decontamination Rooms

Areas provided for the decontamination of equipment are Number 2 areas and should be provided with protective surfaces and hoods as in the diet preparation rooms.

Air Conditioning

Purpose and Necessity

A plentiful supply of filtered fresh air with precise control of temperature and humidity is essential for promoting the health and growth of animals, preventing infections and epidemics, reducing the possibility of large losses in population and investment in experiments, and ensuring their validity. Sudden changes or extremes in temperature or humidity will occur if control is not provided and the results can be disastrous.

For the protection of personnel, particularly in areas where radioactive materials are present, filtered air at controlled humidity and temperature is required for protection against the inhalation of hazardous dusts and to prevent sweating.

General Specifications

Central air conditioning systems are indicated for large buildings which are subdivided into numerous small areas. Fresh air should be drawn in through conventional filters, washed, dehumidified to the desired point by refrigeration, and reheated for distribution by a duct system to each segregated area. Individual automatically controlled air reheaters can be installed on the air inlets to rooms where precise control of temperature is required. Breeding areas, for example, will require better regulation and higher temperatures than areas for stock rabbits. Air volume control dampers and directional diffusers can also be provided in room inlets to regulate the number of air changes and to control the velocity and distribution.

There should be no recirculation of air, and each room should be supplied independently.

All filters and duct work including controls should be readily accessible for cleaning and decontamination.

All rooms should be operated under slight negative pressure except the infection-free breeding rooms which should have a slight positive pressure.

Air from radioactive areas should be exhausted through Dust Stop or equivalent filters and Chemical Corps filters in addition. Gas scrubbing or absorption on activated chars may be required to remove gaseous products which may result as a product of metabolism, or from inhalation experiments.

Detailed Specifications

Non-Radioactive Areas

Rooms in which animals are housed should be supplied with sufficient air to effect ten changes per hour at velocities not in excess of 50 feet per minute and should be maintained at 70 to 78°F plus or minus 2°F, depending upon the occupancy, and 50% relative humidity. Rats will require 74°F, mice 76°F, breeding colonies up to 78°F, and rabbits do not require over 70°F.

Rooms for food preparation, sterilizing, and equipment cleaning require only fresh air ventilation, but air conditioning is preferable.

Radioactive Areas

Rooms in which experimental animals are housed in accordance with specifications for a Number 1 area should be supplied with sufficient air to effect at least ten changes per hour and should be maintained at 72 to 74°F and 45 to 50% relative humidity. The air currents should be directed downward over aisles between cages at a velocity of 50 feet per minute and should be exhausted after passing through the animal cages at points near the floor. The purpose of directing the air currents in this manner is to provide dust free air for the personnel and to minimize the amount of dust in the room emanating from food, dried fecal matter, falling hair from animals, etc.

Rooms containing experimental animals which are operated as Number 2 areas should be supplied with 15 changes of air per hour at 72 to 74°F and 45 to 50% relative humidity. The air currents

should be directed downward in aisles between cages at velocities up to 75 feet per minute in the same manner and for the same reasons as in Number 1 areas.

For better protection, vertically adjustable screens can be mounted in front of the animal cages to ensure a positive control of air flow, first to personnel, then through the cages, and out. Figure 6 illustrates this arrangement.

For maximum protection, hoods should be provided.

Rooms in which diets and special foods containing radioactive isotopes are prepared rate as Number 2 areas. The introduction and mixing of the isotopes and filling and covering of the food containers should be performed under hoods, with 100 to 150 feet per minute air velocity across the openings. Fifteen air changes per hour should be provided in the rooms with the temperature held at 72°F and 45-50% relative humidity.

Decontamination and equipment cleaning rooms rate as Number 2 areas and require the same air conditioning specifications as for diet preparation rooms. Hoods or their equivalent should be provided, under which strippable films can be removed, and cages and waste collecting trays, food containers, and water bottles can be cleaned and decontaminated.

Duplicate and Stand-by Equipment

Provision should be made to prevent the loss of large numbers of animals and loss of investment in experiments in the event of protracted failures of the heating, ventilating and air conditioning equipment. If there is reasonable assurance that failures of the power supply external

to the laboratories will be few in number and of short duration, no separate source of power will be necessary. The principal filters, fans, heaters, and their motors should be in duplicate to guard against individual failures and to permit repairs and cleaning without interruption. Serious consideration should be given to the desirability of providing duplicate air conditioning units for areas employing radioactive materials and those in which long-term experiments are being conducted.

Equipment

From the great variety of small animal cages offered by equipment manufacturers and in use in existing laboratories, the type which we believe will meet all requirements for rats, mice, hamsters, and guinea pigs can be described as a simple drawer type with wire mesh or perforated bottoms and separate trays for collecting waste material. It is adaptable and interchangeable because different small animals can be housed in it and because multiples of the base size cage can be held on the same racks used for the base cages. In outline it is a simple rectangular box, and can be so designed as to present smooth surfaces with a minimum of joints or places where dirt or radioactivity can accumulate and be difficult to eliminate. This cage can be readily manipulated and the animals in it are accessible.

The size of the cages for rodents should be selected on the basis of the size of the animals to be housed and the number of animals per cage. In Figures 2, 3, and 4 tentative cage sizes are indicated, and in Appendix A the requirements are analyzed and various sizes are presented in Tables III, IV, VII, VIII, and IX.

Standard water bottles are ordinarily attached to the front or rear ends of these cages and food containers can be placed inside or hung on the outside.

The mesh bottom type cage is being successfully used by several large colonies for breeding. Nesting material is supplied in the cages. Where it is desired to carry out breeding directly on shavings or other fecal absorbent material, false solid bottoms can be placed in the mesh bottoms cages.

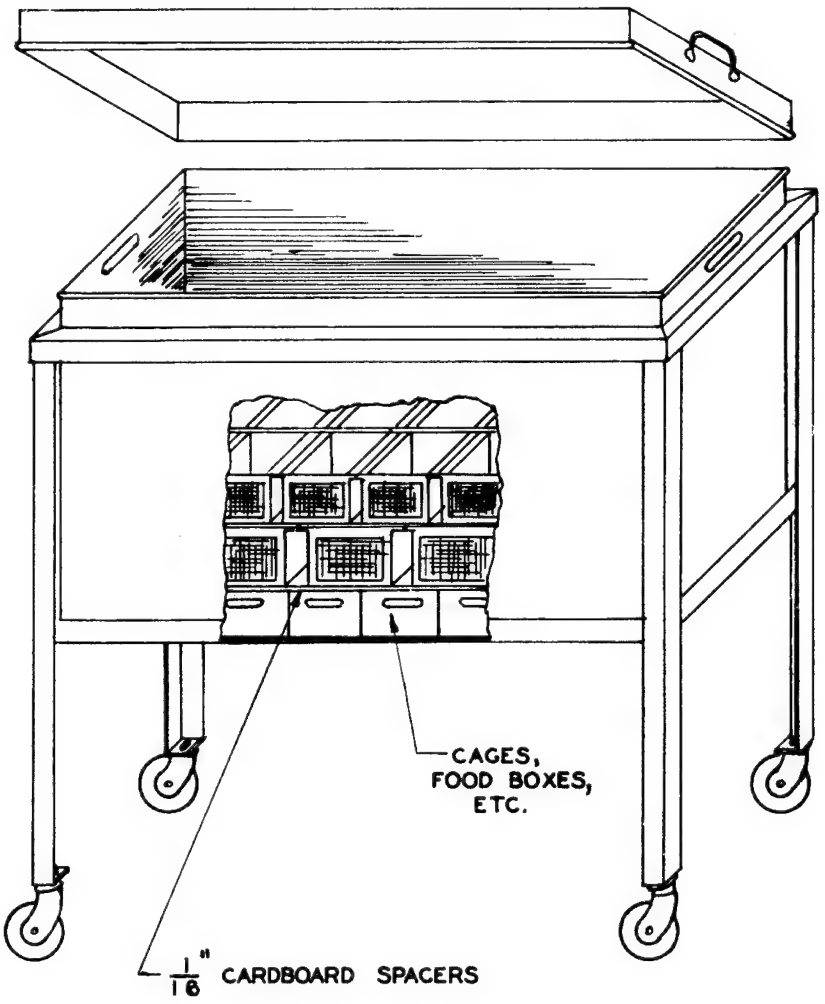
Cages for special purposes must be designed to meet the requirements of the experiment.

Racks holding the cages should be standardized as far as possible and should have wheels to facilitate moving the entire stand into a cleaning area. They should be designed to present the least possible joints or places where dirt, dust, or radioactivity can accumulate and be difficult to clean or decontaminate. Welded tubular construction or its equivalent is suggested and for radioactive areas a rack that can be dismantled to a condition where it can readily be decontaminated may be desirable.

Portable service tables and containers should be standardized also as to size and construction and should be easily cleaned or decontaminated. A service table of the style shown in Figure 7 is recommended for use in the radioactive areas to transport all material and equipment save cage racks through the corridors.

Where it is desired to minimize contamination of service corridors in the radioactive areas, a stainless steel box mounted on casters can be used for transporting a single cage rack at a time from the colony room to the decontamination area. The interior walls of the box should be smooth

UTILITY WAGON
FOR
SERVICING RADIOACTIVE AREAS



SUGGESTED MATERIAL FOR BOX AND COVER — STAINLESS STEEL
INTERIOR SURFACES OF BOX AND COVER COATED WITH STRIPPABLE FILM

FIGURE 7

so they can be covered with coatings to facilitate decontamination. The box should be designed also so that its inner surfaces can be easily reached by cleaning personnel.

The selection of cages and equipment for larger animals, such as rabbits, cats, dogs, and monkeys, should be based on the same considerations as those for rodents and should meet the same general specifications except that the cages will not be of the drawer type.

Suitable mechanisms can be designed for automatically feeding, watering, and removing wastes, but it is doubtful that an earning on the investment could be effected except in the case of a large number of animals living on identical rations on long-time experiments, or in very large stock breeding colonies. Laboratories having a large number of comparatively small colonies being used for a variety of experimental purposes would not benefit materially, except for some experiments where special remote control procedures are indicated.

Paper conveyors under the cages for collecting wastes have proven to be satisfactory in many non-radioactive animal colonies. In radioactive areas, however, plain stainless steel trays have advantages. The trays can be easily cleaned and decontaminated and can be protected with coatings or strippable films if required. Some usable materials for this purpose are available, but further study will without doubt disclose more desirable ones. The contents of the trays can be treated with acids to minimize odors, and dust. The amount of material to be disposed of and the chance of spilling waste will probably be less than with the paper conveyors.

The selection of equipment for the preparation of diets will depend upon the numbers and types of animals to be fed and watered and the diets which are to be furnished. Large animal laboratories are equipped with appropriate weighing, mixing, sterilizing, and cooking units. The design of equipment for the preparation and handling of radioactive foods must provide for ease of decontamination. Where possible stainless steel is recommended.

In like manner the selection of cleaning, sterilizing, and decontamination equipment will depend upon the numbers and types of animals in the colonies. Large animal laboratories not working with radioactive materials are equipped with dipping tanks and spray chambers where hot water and disinfectants are used and with steam jet chambers into which racks and cages can be wheeled. Sinks and sterilizers are also provided for water bottles and food container cleaning.

In areas where equipment which has been exposed to radioactivity will be cleaned and decontaminated, hoods or their equivalent should be provided for all operations. Totally enclosed machines should be used for cleaning cages, food and water dispensers and trays. Covered containers will be needed in which coatings or strippable films from racks, trays, service carts, and the like can be stored.

II. MATERIALS OF CONSTRUCTION

Buildings

Our recommendations for construction and equipment materials for the conventional areas of the laboratories favor those which have proven their worth, and the selections for the radioactive areas are based on a careful appraisal of current information. No proven specifications for facilities for radioactive experimental work with animals is in existence. It would therefore seem in order to institute a program for testing and evaluating a limited number of promising materials and designs in order to determine those which will offer maximum utility with minimum cost.

The principle structural materials for the buildings should be reinforced concrete and steel, as they meet the requirements for vermin-proof, fire-proof, airtight construction. If plain concrete exterior walls are not considered sufficiently attractive in appearance, they can be improved by brick facings or other architectural treatment.

The interior walls, floors and ceilings should have a dense, hard concrete finish, the purpose being to provide surfaces that can be completed by the application of paint or glazed tile or, in radioactive areas, by special treatments described in the next paragraphs.

In Number 1 and 2 radioactive areas, the following additional provisions should be made:

All floors should have two impervious removable layers over a metal base, as follows: The concrete should be covered with cut-back asphalt. A sandwich of aluminum foil and Kraft-paper should cover the asphalt and a 3/16" light-colored, rubber

tile should be set on this base in an emulsion type cement. Tile floors can be coated with water emulsion wax. This type of construction provides triple protection for the concrete. In the event of contamination, either the wax coating can be scraped off and removed or the tile can be replaced in small sections inexpensively, or the tile, cement, and even the Kraftpaper aluminum-foil sandwich can be replaced if necessary. Floors of offices, laboratories, and corridors will preferably be of rubber tile or, as a second choice, asphalt tile.

The preferred choice for walls and movable partitions consists of metal panels. Joints can be filled with any one of a number of suitable vegetable oil, or asphaltic caulking compounds. After caulking, the joints can be covered with Polythene or Vinylite adhesive tape. Wall areas where contamination is expected can be covered with Polythene or Vinylite sheeting. On all surfaces where contamination may be expected but which are unsuitable for covering with sheeting or tape, such as door knobs, faucet handles, etc., apply three coats of strippable film.

Vinyl or Alkyd coated steel ceilings with coatings similar to those described for walls, are preferred.

Number 3 radioactive areas will be intended for small scale experimental work using radioactive materials and techniques which have not yet been specified. The basic Number 2 area specifications will apply, and provisions should be made in these areas for hoods and remote control of operations.

Equipment

Equipment for use in non-radioactive areas, consisting of cages, racks, feeding and watering devices, service carts, and containers, can be constructed of galvanized iron which has proven to be the least expensive satisfactory material in many animal colonies. The value of stainless steel and plastics material has not been demonstrated, but numerous trial runs are being made. In some instances stainless steel pans for use under cages and stainless steel bottoms for cages have been adopted. Further experimenting to find an ideal material is therefore indicated.

Conventional materials can be used in the construction of equipment for food preparation and also for sinks, tanks, sterilizers, and other facilities required in the equipment cleaning area.

In radioactive areas the preferred material for cages, racks, waste collecting trays, feeding devices, and service carts, is stainless steel, but here again there has not been a sufficient search for the best material. Stainless steel will withstand water and detergent washing and acid pickling. All equipment except cages and food containers which the animals can reach can be coated or covered with strippable materials. Stainless steel or other covers should be provided for the portable service tables or carts which are used for transporting radioactive foods and covers for individual food containers may also be advisable. Radioactive cages can be moved for cleaning and decontaminating in covered service carts. Racks can be covered by vinylite sheeting or can be placed in enclosed trucks for transport.

The preferred material for sinks is stainless steel with rounded corners and sloping splash surface. For those which may be expected to become contaminated frequently, preformed rubber liners or a strippable

film should be provided and extended down into the drain pipe as far as possible. A stainless steel grill should cover the bottom to prevent splashing and to protect the liner. Faucets should be of stainless steel and should have non-splash nozzles.

Drain piping for laboratories and for disposal of radioactive wastes should have flanged joints with Teflon or equivalent gaskets. By this means the pipe line can be dismantled if necessary for decontamination. "Duriron" will outlive cast iron and is preferred wherever its cost can be justified.

Solid wastes should be collected in covered waste containers. These can be 25-gallon metal barrels. They should be coated on the inside with strippable film and supplied with a heavy wall-paper bag as a liner. Protection is thereby afforded to the personnel and decontamination is facilitated.

Hoods can be constructed of either metal or Transite covered with Polyken tape. The floor of the hoods should be covered with 1/4" Transite sheet laid over the Polyken tape to give heat protection and allow easy replacement.

Air ducts should be made of stainless steel or "Galbestos" with flanged joints and should be covered with a heavy layer of Duralon.

Decontamination areas are classed as Number 2 areas and basic specifications for materials apply.

III. TECHNIQUES OF OPERATION AND PRECAUTIONARY MEASURES

General

In an animal colony doing radioactive work, conventional non-radioactive animal quarters will be maintained to supply stock animals and to house animals used as controls for experiments being conducted in the radioactive areas. All work involving radioactive isotopes in amount of 1 microcurie or greater will be carried out in separate radioactive quarters.

Non-Radioactive or "Cold" Colony Rooms

In the non-radioactive or "cold" quarters the techniques of operation of the colony rooms will be those generally employed in modern colonies and discussed in great detail in Appendix A. The precise routine to be followed will depend upon the exact nature of the experiments to be undertaken. However, where possible, these general procedures are recommended.

1. Quarters shall be air conditioned to maintain sensibly constant temperature and humidity.
2. Lighting shall be on a definite schedule, in general twelve hours on (during daytime working hours) and twelve hours off.
3. Noise shall be minimized in the colony rooms.
4. Overcrowing of animals should be avoided. Recommended cage sizes are given in Appendix A for each animal.
5. Colony room floors and walls shall be kept clean by mopping as required.
6. Feeding procedure will be suitable for the experiment in progress. Where possible, feed hoppers will be used to minimize frequency

of having to replenish food. Caretakers shall be responsible for providing the desired amounts of food before the animals at all times.

7. Watering will be in general by means of water bottles which must be regularly checked by the operator to be certain water is available to the animal.

8. Cage bottoms shall be cleaned at least twice in a week and more frequently with the larger animals, such as dogs and monkeys. If paper on rolls is used for bottoms in rat, mice, or other quarters, fresh paper should be supplied at least every other day.

9. Replacement of dirty cages by clean ones shall be done generally about every two weeks.

10. Filling of water bottles and diet cups shall be done outside the colony room.

11. Save for weighing and visual inspections, only those operations directly connected with housing of the animals shall be carried out in the colony rooms.

12. Personnel not directly concerned with the care or use of the animals shall not be permitted in the colony rooms.

13. Animal caretakers will check all animals daily for deaths.

Breeding

In the cold area of the animal quarters, breeding facilities will be provided for rats, mice, and other small species if they are used in quantity. These, it is felt, should be operated on an "infection-free basis." Such operation is discussed in detail in Appendix A. Its significant aspects are summarized here.

1. The colony room shall be an isolated area operated under slight positive air pressure so that all air leakage will be out.
2. The colony room shall be vermin proof, without drains or openable windows.
3. One entrance shall be provided through which personnel may enter and leave. This will be provided with facilities where the caretakers, before entering the colony, must strip, shower, and dress in clothes used only in the colony rooms.
4. All food and bedding to be used in the colony will be brought first into a room adjoining the colony room and will enter the colony room only after passing through heat processing equipment to kill parasites and vermin which carry infection.
5. All air used in the colony for heating or cooling shall be carefully filtered to remove infectious dust before introduction into the colony.
6. Dirty cages and refuse shall be removed from the colony room through a sterilizing chamber serving as a lock between the colony room and the outside. This sterilizer itself shall always be sterilized before opening to the colony area and shall never be open to both the colony room and the outside at the same time.
7. Water used in the colony shall be known to be free of infection or distilled before use.
8. In initiating the colony, the colony room shall be carefully cleaned with disinfectant solutions and young placed in it which have been produced by Caesarean operation and maintained in infection-free surroundings. Techniques of the Caesarean

operation for albino rats have been well worked out at the Lobund Laboratory at Notre Dame and described in some detail in Lobund Report No. 1*.

9. The colony is to be built up from this stock and no animals from outside sources are to be introduced into the breeding colony.

10. In sterilizing food, such components as purified vitamin oils, salts, and other similar pharmaceutical components of the diet need not be heat processed, but must be scrupulously clean before introducing into the colony. Grain fractions should be heat processed. Procedures have been worked out at Lobund on ONR projects and can be obtained by properly "cleared" personnel.

11. Only personnel directly concerned with care of the animals shall be admitted to the colony.

12. Only one species will be handled in one breeding colony room.

13. All equipment used in the colony room such as pails, mops, tools, etc., shall be sterilized either by heat or disinfectant solutions before being taken into the colony.

The actual breeding procedure followed in the colony may be along conventional lines. While highest production rates per adult rat are obtained by continuous monogamous techniques, economic production can be obtained by polygamous procedures and probably results in more vigorous stock. Breeders should be used for about one year and then discarded or used for other purposes. Particular care should be given to maintaining adequate quantities of food and water for lactating mothers.

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* Lobund Report No. 1, page 12, November, 1946

Quarantine Area

Quarantine facilities will be available in the cold area and all animals brought in from the outside for use in any part of the overall colony will be delivered to this area before entry into the general quarters. Procedures for handling the animals will be the same as in the general cold animal quarters with these additional factors. Animals will be carefully watched and examined for any evidence of disease or infection. They will be freed of vermin by appropriate techniques, such as dipping in disinfectant solutions, and dusting with DDT or Rotenone compounds. Antitoxins such as rabies shots and distemper vaccines will be administered here. Necessary worming of dogs will be done. This area is a primary line of defense in the colony against introduction of disease. It should be in the hands of capable personnel, well versed in animal care, and who are familiar in detail with symptoms of the various infections possible with the different species.

Diet Kitchen

Space and equipment will be provided wherein diets may be prepared. In the small colony, storage of diet components may be in the same room as used to prepare the diets, while in larger colonies a storage room held at reduced temperature will be desirable. In the diet kitchen itself scales and mixing equipment should be available. Uniformity of mixing is essential if consistent results are to be obtained in feeding experiments. Ingredients which must be added in very small amounts can well be premixed with moderate quantities of other components of the complete mix and then the premix blended with the remaining ingredients. The kitchen should be kept scrupulously clean to avoid attracting wild mice, rats,

and vermin. Mixed diet being stored for use should be kept in tightly closed containers.

Cage and Equipment Cleaning Facilities

Cage and equipment cleaning should be done in a separate area rather than in the colony and other rooms. In the small colony, hand cleaning by brush scrubbing in detergent solution will be suitable. TSP solutions are widely used and serve to loosen adhered fecal matter without damaging galvanizing significantly. After cleaning in detergent solutions, the cages should be thoroughly washed in clean water held at close to the boiling point. Depending on the degree to which steps are taken in other operations of the colony to prevent infection reaching the colony animals, the cages would be either air dried or placed in a steam sterilizer and exposed to live steam or actually sterilized at 5-16 psi. If actual sterilization is used, the cages should pass from the sterilizer into a clean area wherein only sterilized equipment is stored rather than back into the general cleaning area where infected cages are apt to be.

In the large colony the operations up through atmospheric steaming can be more cheaply handled on mechanized cage cleaning equipment. In such equipment, high velocity streams of cleaning solution, water and steam are substituted for the hand operations. Both batch and continuous styles of equipment are available, which permit one man to clean a large number of cages per day. If sterilization is desired, this operation is most cheaply done batchwise because of the high cost of continuous equipment.

Bottoms pans and feed jars will be handled in the same fashion as cages. Water bottles, drinking tubes, and stoppers will be cleaned according to good practice for laboratory glassware.

Bedding Material

Bedding material will be required in the breeding colony and in the bottoms pans under the cages. "Serval" bedding is recommended, since it can be relatively easily handled for sterilization and has a high absorbent capacity for fecal and urine odors. If the colony is large, a simple device similar to fertilizer spreader can be used to spread a uniform layer of bedding in each tray.

Best procedure appears to be to have sufficient spare trays so that a rack of them can be filled with fresh bedding in the bedding storage room, wheeled to the colony room, substituted for dirty trays, and the dirty trays wheeled out of the colony for cleaning and refilling. This will reduce confusion in the colony room.

All bedding should be sterilized before use. If the colony is large, a room can be set aside for storage of material as received. As required, a reasonable quantity will be sterilized and stored for use in tightly closed containers in a clean room distinctly separate from that used for newly received material.

Radioactive or "Hot" Quarters

The quarters described in the previous general section on cold quarters serve chiefly as sources of supply of animals and materials and as housing for control animals incident to the studies on the effects of external, inhaled, and ingested radiation going on in hot quarters. In these hot quarters the general techniques of cold operation will be used with the addition of such techniques as are required to protect the personnel from radiation hazards and the animals from radiation exposure other than that connected with the experiment at hand.

Particular efforts should be made to segregate work at different radiation intensity levels. It has already been suggested that three levels be considered. In Number 1 areas work at levels from 1-100 microcuries shall be done. In Number 2 areas work at levels of 0.1-10 millicuries shall be done. More hazardous work shall be done in Number 3 areas. Number 1 areas will be chiefly animal colonies and corridors. Number 2 areas will be animal colonies, diet praparation areas, equipment cleaning and decontamination areas. Number 3 areas will be special animal colonies on work such as radium ingestion or gamma ray exposure. In all areas operation will have to be in accordance with standards adopted by the site.

While exact specification of the personnel precautions of the radioactive quarters is beyond the scope of this report, these general procedures are suggested as having been advantageously used in currently operating radioactive colonies. Workers and all other personnel must enter the radioactive quarters through a health physics monitoring area. Here pocket ionization chambers and film badges will be picked up and required lab clothing, gloves, and footwear put on. Personnel will submit urine samples and appear as requested for special hand studies, blood count, and general medical examinations. Workers should not smoke, eat, store or prepare food in the radioactive areas.

Personnel should be well instructed as to the hazards of their work so that they will enthusiastically conform to regulations as to extent of exposure and handling of radioactive materials. Personnel should be used who are known to be meticulous as to details and who evidence a natural ability to do their manual tasks easily and well. A good general rule for all personnel working in the hot quarters will be to know at all

times the degree of hazard to which they are exposed. If they don't know, they should take steps to find out before working in the area.

Radioactive or Hot Colony Rooms

The colony rooms containing animals exposed in one way or another to radioactivity will be the focal point of experimentation in the radioactive laboratory. It is felt that the following general operational procedures will apply in most situations.

1. All recommendations given for cold colony room operation shall apply save as hereafter modified.
2. There shall be no recycle of conditioned air used for winter heating and summer cooling. Air should be filtered through Dust Stop filters or their equivalent before entering the colony and through Dust Stop and Chemical Corps fine filters before being exhausted from the colony. Preferably at least two Chemical Corps filters should be used in series to provide greater protection. In cases where the radioactive material given to the animal may be obtained as a gaseous product of metabolism, exhaust air from the colony will have to be treated to remove such gaseous products. Appropriate gas scrubbing or absorption on activated chars will be required. Air flow in the colony shall be so directed as to protect the colony worker (see Figure 6).
3. Monitoring of all equipment in the colony room or any brought into it shall be routine. In general policy shall be to operate so that the rate per hour of radiation from any surface shall not exceed the average hourly rate which will give in an eight-hour working day the maximum permissible daily exposure set up for the site. The problems of safe levels of operation have

been discussed at some length with Dr. R. D. Evans of the Massachusetts Institute of Technology and our conclusions from these discussions are as follows. While many sites use a figure of 0.1 roentgen per eight-hour day as the maximum permissible daily exposure, most actually work at 1/10 of this level. It appears probable that the maximum permissible hourly rate, hereafter abbreviated MPHR, of radiation for surfaces and equipment, will vary with the animal study at hand. We feel that it should not exceed 1 milliroentgen per hour.

In decontaminating equipment and surfaces, they shall be cleaned to where there is no significant beta radiation. 0.1 mrep of beta radiation per hour at the surface shall be considered a satisfactory value for this report and will be termed hereafter NSBR.

4. Use of shielding shall be practiced whereever possible to reduce radiation intensities. The use of cardboard inserts in bottoms trays to shield from the trays absorbed radiation, covers on containers such as food dishes or bottoms trays full of hot fecal matter are typical examples. It is recommended that an experimental colony be set up and various possible shielding techniques studied.

5. Wherever possible, equipment which will be exposed to radiation and not directly to the animals, should be coated with strippable film. Cage racks, service racks and tables, radioactive waste containers and bottoms trays are typical examples. Such a procedure will permit decontamination with a minimum of wet cleaning.

6. Bottoms trays shall be freed of fecal accumulation daily or as required to keep radiation levels during use under cages, below MPHR. They shall be cleaned and decontaminated frequently enough to keep their radiation level, when free from fecal contents, below the MPHR.

7. Cages likewise shall be cleaned and decontaminated frequently enough to keep their radiation below the MPHR.

8. In bringing food supplies and water to the laboratory quantities handled and shielding shall be such that the MPHR shall not be exceeded by the surfaces of the service table or rack exposed to personnel.

9. In case of spills of radioactive material containing wastes, food or other materials, the spilled material shall be removed immediately and the surfaces contacted by the spilled material monitored. If they are not below a level of MPHR, they should be decontaminated. The procedure will depend upon the construction used, as outlined under Materials of Construction.

In handling animals, cages, bottom trays and other equipment in the colony rooms, caretakers shall wear rubber gloves. Care should be taken in handling animals to avoid being bitten, and in case of a bite, personnel should, of course, report immediately to the medical department for proper treatment.

Colony rooms shall be kept scrupulously clean, with frequent mopping of walls, floors, and ceilings to prevent dust accumulation. Frequent monitoring should be practiced and when readings above MPHR are obtained, decontamination steps should be taken to reduce to a level of NSBR.

In Number 2 area colonies (.1-10 millicuries) caretakers should wear masks to prevent inhalation of dust containing radioactive materials. Supplied-air masks are the only type which offers complete protection and will be required in the presence of radioactive gases. The more convenient Army assault masks using Chemical Corps filter paper will be satisfactory in many situations. Frequent monitoring of the colony room air should be carried out by the Health Physics department and their recommendations as to type of masks to be worn followed.

In Number 2 areas the use of plastic or heavily filled canvas containers in front of the cages as shown in Figure 6 is recommended. These will serve essentially to place the cages in a hood and will furnish considerable additional protection to personnel as regards both direct and radiation hazards.

Diet Preparation Rooms

It appears probable that there will be many instances where radioactive materials will be incorporated into the diets fed to the animals. Such diets are apt to be made from grains and other components having a high fines content and consequently subject to dusting. The addition of radioactive materials to such diets by mixing will result in formation of hazardous radioactive dust and should be done under a hood with at least 100 feet per minute air velocity across the hood opening using a covered mixer or suitable dry boxes.

Like the animal colony rooms, the diet preparation room will be subject to radioactive contamination by dust from the diets and from spills of diet material, or the more radioactive solutions or preparations to be mixed with the diets. Cleaning of the rooms, air monitoring, and cleaning up of spills should be on the same basis as the colony rooms.

Spills of sizable quantities of radioactive material should be monitored before cleaning up to determine the degree of exposure to persons carrying out the decontamination. If significantly above MPHR, decontamination should be carried out under the supervision of Health Physics personnel.

Equipment Cleaning and Decontamination

Cleaning and decontamination of all equipment should be done at a central location where adequate supervision of all operations can be economically maintained. This will require transport of radioactive contaminated cages, bottoms trays, feeders, racks, and the like from the colony rooms to the cleaning area along corridors serving as general personnel access means to the several radioactive facilities. Similarly, hot diets prepared at a central point will have to be transported to colonies for use. The use of service wagons of the type shown in Figure 7 is recommended. All hot equipment save cage racks will be placed in these service wagons and covered before being moved into the corridors. The outer surfaces of the wagons shall be regularly monitored and always kept at NSBR levels or lower.

All equipment which does not come in direct contact with the animals shall be regularly protected by strippable film. Included would be cage racks, bottoms trays, service wagons, waste containers. Decontamination thus becomes a question of stripping off the films, leaving base items at essentially background radiation levels. Such dry decontamination should be done in a hood-like structure in the decontaminating area, and clean equipment immediately moved to a clean storage area for recoating before use. In cases where coated equipment is heavily contaminated, the item can be coated further before stripping. This will serve to cover over

the contamination and shield the operator during decontamination. Strippable coatings on cage racks can be stripped before removal from the colony rooms, thus rendering them essentially clean before entering the corridor. This exception to the general rule of decontaminating at a central point appears justified due to the difficulty of confining radioactive dust on the racks during transport to the central cleaning area. As an alternate, the racks can be placed inside trucks provided for the purpose of transporting them through corridors.

Cages, feeders, and water bottles should be cleaned and decontaminated in tightly closed batch or continuous washers. Hot TSP solutions shall be used, employing high velocity jets to dislodge adhered excreta. They should be rinsed thoroughly with clean water and monitored. Items which are still above NSBR should be returned to the TSP and allowed to remain for 2-4 times the length of time allowed originally. They should then be rinsed and monitored. If still not low enough in radioactivity, they should be soaked in nitric acid, rinsed, and monitored. If still too hot, they should be stored for radioactive decay or disposed of with other radioactive wastes.

If extensive experimental work is undertaken which regularly results in cages which cannot be readily decontaminated, the use of plastic liners for the regular cages or complete plastics cages should be considered.

APPENDIX A

CURRENT OPERATING PROCEDURES IN ANIMAL COLONIES

The design of adequate quarters in which to house laboratory animals requires understanding of the characteristics of the animals, of environmental conditions required for their normal growth, and knowledge of the experiment in which they are to be used. Such data are presented herewith for the most generally used animals. Much of the data have been collected by visiting operating colonies used for various purposes. A list of these colonies is given in Appendix B. During these visits data were also collected on many of the variables of colony operation, such as cage cleaning, labor requirements, and insect control.

In general, the engineer who designs animal quarters must bear in mind the obvious fact that he is dealing with a living creature whose requirements vary with age. The space used to house the animal will depend upon the ultimate age to which the animal is to be maintained. Facilities for feeding and watering must be provided. Provision must be made to remove excreta and maintain the colony in a sanitary condition. The animal should be protected from conditions and materials which may introduce or cause disease.

Relatively few of the animal colonies now in operation can contribute much design information to animal facilities for a specific experiment. Most are planned to provide for general care and housing and usually provide for ready conversion of facilities within certain experimental limits. An effort has been made to obtain data on current practice in

such laboratories as well as opinions from their operators as to how they would change their design and procedures if they could utilize experience in reconstruction.

Construction Details

There is almost universal agreement among colony operators that the animal colony room should have walls, ceilings, and floors which are vermin-proof and easily cleaned. Glazed structural tile, glass bricks, or gloss-painted surfaces are preferred for walls. Sheet metal has been used very successfully when adequate sealing of panel joints has been effected. Concrete floors are widely used. These are particularly good if densified or sealed with suitable paints. Well-smoothed plaster or concrete ceilings were seen and liked in most colonies.

While many colonies seen were equipped with central floor drains permitting frequent flushing of the colony room by hose, many operators have found that if good facilities for cage cleaning are provided, occasional wet-mopping of the floor is entirely adequate. Floor drains are regarded as a source of vermin and their elimination is strongly recommended by a number of operators.

Avoidance of ledges where dust may accumulate is also recommended. Where possible, glass blocks may be substituted for windows, thus eliminating window sills. Where possible, exposed piping, duct work, drop lights and the like should be avoided, for such dust accumulators require cleaning and tend to harbor vermin.

Lighting

Most colonies seen used incandescent lamps for general colony illumination. A few use fluorescent lights. One laboratory doing vitamin assays had tried fluorescent lighting and found their results sufficiently altered to justify a return to incandescent lamps.

Heating and Temperature Control

Control of temperature was generally practiced in animal colonies observed by us. None of them employed a temperature cycling schedule, choosing instead to maintain constant conditions day and night. The hazards of sudden changes were stressed by all colony operators. The desirability of controlling humidity is recognized. About half of the colonies seen were equipped to do so.

Some of the older colonies and those where capital costs must be kept at a minimum employ radiators for heating. In such installations exhaust fans are used generally for odor control. Most of the newer colonies use forced circulation conditioned air for heating.

Colony forced circulation air-conditioning systems are generally designed for 50-70% recycling of air but are commonly operated on 100% fresh air without recycling, in spite of the fact that no serious odor problem developed when operating at designed recycling rates. Recycling is most frequent in very cold weather or very hot weather, in an effort to reduce the load on the conditioning system. Rates of air circulation vary from 3-17 changes per hour with most colonies operating at 5-9 chages per hour. The design of equipment in one colony is planned to provide 1-2 CFM of air per square foot of colony floor.

Filtration of dust from incoming air is usually standard on such systems and is commonly through fiber glass filters. This is of considerable importance in preventing introduction of infectious dust into the colony.

An important feature of many heating systems is an auxiliary source to insure against the loss of many animals should the main system fail.

Such a precaution is especially important for colonies in which long-term experiments are being run.

The design of the ventilating system must be such that the introduction of air to, or removal from the colony room does not cause drafts of air to be directed on any animal. The use of circular diffusers in the ceiling for introduction of air is common. Some colonies employ conventional louvered-duct openings for introduction and removal of air.

Several systems were seen in which air from main conditioning systems was adjusted as to temperature and moisture at the inlet to each conditioned area by booster heaters and humidifiers. Where several rooms at different conditions are desired as in colonies maintaining both holding, breeding, and experimental colonies, such a procedure has merit.

Cage Design

The trend in cage design appears to be towards simple rectangular shaped cages, generally made of wire mesh. These are supported on movable racks and provided with excreta-collecting devices placed under them. These principles result in a cage which is easy to clean and in which excreta does not accumulate in the space occupied by the animal.

For small animals a drawer-type cage is finding wide acceptance. The cages are supported from runners placed on the underside of solid shelves. The shelf forms the top of the cage. Excreta-collecting means are placed on the top side of the shelf below the row of cages. Most users of these cages employ pans beneath them to collect fecal matter, but a few employ paper in rolls mounted on supports at one end of the rack and drawn under the cages in a continuous sheet. These procedures for disposal of fecal matter are discussed in greater detail under cage cleaning.

One laboratory visited employed a cage designed to facilitate the use of a vacuum cleaner to remove soiled litter. The rectangular cage is made either of expanded or punched metal and has an integral stainless steel bottom pan. Access to the cage is by means of a door forming the front side of the cage. A layer of granular bedding material is placed on the bottom pan and the animals are placed directly on the bedding without a metal floor screen. Two or three times a week the soiled bedding is removed by using an industrial vacuum cleaner with a rectangular nozzle.

In some laboratories using pelleted feed, feed hoppers have been designed as an integral part of the cage.

At a number of the colonies, a single large size of cages has been adopted as standard. Inside of each cage are provisions for insertion of removable partitions. In this way, single and multiple caging is possible with stocking of only a single basic cage size. Users of such cages have observed that the grooves provided for the partitions are difficult to clean.

Materials of Construction for Cages

Galvanized iron wire and sheet metal are the most widely used materials for animal cages. Frequently, aluminum lacquer is applied over the galvanized metal and cages of these materials give long service and withstand washing with such cleaners as tri-sodium phosphate.

Colony operators were generally unable to provide information on probable durability of cages. A few stated that stainless steel gave two to six times the length of service which might be

expected from galvanized metal. Stainless steel costs approximately two to three times as much as galvanized metal and is probably slightly easier to clean because of greater surface smoothness.

In a few colonies cages are made of expanded or punched metal. Other than ruggedness, they did not appear to offer special advantages. Wooden cages are used and well liked for housing such small animals as mice.

Feeding

It is not proposed to report in detail on the subject of dietary composition. Types of diets in general use and their effect on colony design and operation will be indicated. Among the twenty-six colonies from which information on diet was obtained, thirteen used commercial diets, nine used diets of their own preparation, and four used both commercial diets and those of their own preparation.

Among commercial diets, pelleted forms are most favored. When used in feed hoppers, it is possible to make several days supply available at one time, thus reducing materially the labor of supplying feed to the animals.

Commercial diets were not favored by some operators because of the lack of uniformity in terms of nutritive value. Some attempted to correct this variability by supplementary feeding, while others prepared entire diets for exclusive use in their colonies. Most of these diets were granular or powdered, but a few colonies had pelleting equipment. In two laboratories visited, means had been provided to sterilize the prepared diet and thereby eliminate infectious material normally found in certain dietary components, especially grain fractions. The reduction of infection by heat processing of the diet will be discussed in more detail under the section on infection control.

Diet preparation in the individual laboratory requires increased labor for colony maintenance. It also places the responsibility for maintenance of diet quality on the colony staff. Some operators feel these additional duties to be an unnecessary burden, while others feel sufficiently improved results are obtained to warrant such procedures.

Automatic feeding equipment was seen in only one colony. For such a procedure to be practical, a large number of animals must be fed the same diet. This is not common in most animal colonies, except in breeding and stock units. The device seen consisted of a food trough running through a battery of rat cages mounted on racks. Through this trough moved a chain which dragged food along with it. The rats were allowed to feed at will so that as long as feed was constantly being delivered by the chain at the end of the cage battery opposite to the point of supply, the rats were assured of a continuous supply of food. Feed mixtures must be so formulated as to not bridge. The procedure has materially reduced the labor of feeding. Automatic watering is also employed in this colony and will be described in the section covering watering.

In several colonies, feeding arrangements were provided to permit reasonably accurate estimation of food intake. All the devices seen were based on the assumption that all food not actually consumed by the animal remained in the feeder. By weighing the feeder before and after use, food intake was measured.

Watering

The most widely used method of watering animals is from an inverted bottle fastened to the cage and closed with a rubber stopper through which is passed a single glass tube. The end of the tube external to the bottle

is extended into the cage at an angle to a point where the rat may conveniently reach it. Usually this point is high enough so that the animal will not hit the tube in walking around the cage, but low enough so that the rat may readily reach it by standing on its hind legs.

Various modifications of this method were seen. Many colonies use graduated containers to permit direct estimation of the water intake. One laboratory has developed an aluminum tube to replace the glass one on which they had experienced high breakage in cleaning with injury to personnel. Another laboratory is planning to use standard milk bottles for water bottles for water bottles. This will permit the use of standard bottle washing equipment.

In most colonies the use of automatic water devices would require individual valves for each cage. Such a unit has been used with indifferent success in one colony, consisting of a fixed water feed-pipe fitted with a pet cock which delivers water at a dropwise rate to a holder mounted on the side of the cage. Overflow drains from this holder are provided. Such a service was seen at another laboratory visited, but was said to function poorly and to be prone to clog and stop due to its low rate of flow and resulting accumulation of rust.

In the animal colony using automatic feeding as described in the previous section, a watering trough runs through each row of cages parallel to the feed trough. The water trough is made from 3/4" electrical conduit with 3/4" holes cut periodically in its top side. Constant flow is maintained in the trough and can be easily checked by observing the drain at the discharge end. This procedure is applicable only where cross-contamination between cages is not feared. Such systems do not lend themselves to measurement of food or water intake.

In general, animal colonies are operated with the drinking water used for human consumption by the staff operating the colony. The content of the water supply must be known with respect to bacterial and mineral composition. Distilled or boiled water can be used if no natural source is acceptable.

Cage Cleaning

Cage cleaning in the animal colony involves two main functions. The first is the frequent removal of excreta and the second, the actual cleaning of the cage itself. The term "bottoms" is generally used to designate the collecting device placed under the cage to catch excreta. In cages having mesh floors, the "bottoms" device is usually a pan filled with an absorbent material such as sawdust, wood chips, ground sugar cane (bagasse), or paper. In cages having a solid floor, the absorbent material is placed in the cage directly on the floor. A recent innovation seen in a number of colonies was the use of a continuous sheet of non-absorbent paper under each row of cages on a rack. The paper is supplied from a roll placed on a hanger at one end of the cage rack and drawn across under the row of cages. The removal of the soiled paper from the end of the rack opposite to the roll support serves to draw fresh paper under the row of cages. Each row of cages is supplied with its own roll of paper.

One system seen involved the use of cages with bottoms pans forming the floor of the cage. Ground and extracted sugar cane (bagasse) was used to absorb excreta. This was removed every day with an industrial vacuum cleaner (see above). The operation did not frighten the animals and was well liked by the colony caretakers. Whatever method is used, colony operators plan to clean the cage bottoms twice a week, or even more frequently. With the easier systems (such as the use of paper), bottoms

may be quickly and easily renewed each day. This serves to keep cages cleaner and keeps odors at a low level with fewer air changes.

The other phase of cage cleaning is the complete cleaning of the cage proper. This is done much less frequently, seldom more often than once a week and in many instances only once every two to four weeks. In most of the long-established colonies, the cage washing operation was done at a sink located in the colony room, but in most of the newer and larger colonies, a central cage washing area was provided. This centralized procedure has lent emphasis to the desirability of standardizing cage sizes in a colony to permit interchangeability.

In many colonies, washing of cages involves soaking in hot water containing soaps or detergents in tanks or deep sinks. This is followed by hand scrubbing with brushes, followed by washing and air drying. Such a procedure is considered adequate by many operators. Trisodium phosphate solutions are widely used for the soaking operation. Labor requirements for washing cages by these methods were found to vary widely in the colonies visited. One colony reported 4-5 solid floor cages washed per hour per man, when cages were cleaned once a month. Another reported 36 mesh-floor cages washed per hour, when the cages were cleaned every two to three weeks. The cleaning time is obviously a function of how dirty the cages are, i.e. interval between successive washings, and also the construction of the bottoms.

A few colonies have installed washing machines to clean cages. One which was well liked consisted of a motor driven turntable about four feet in diameter mounted in a metal box. Cages are stacked up on the turntable and the box closed. Trisodium phosphate solution is sprayed over the

cages at considerable velocity from nozzles located in vertical pipes placed 90° apart around the turntable. The spraying with trisodium phosphate is followed by rinsing with hot water and treatment by a blast of steam. A ten-minute washing cycle is employed. The machine has a connected electrical load of 5 HP and cost $2500 several years ago.

Another colony used a modified restaurant or hotel-type dishwasher with continuous belt conveyor for cleaning cages. A synthetic detergent was employed in the washing phase and this was followed by a hot water rinse, steam blast, and air drying.

Bottoms Material and Bedding

As noted above, a trend appears to exist among animal colony operators to use mesh-floored cages with suitable bottoms trays placed below them. It is almost universal practice to place some absorbent material in these trays to absorb the urine and hold the feces. While many materials were seen in use for this purpose, ground and extracted sugar cane (bagasse) was most frequently preferred. Many operators using this material remarked that its ability to absorb odors was greater than other materials they had tried. Wood chips, wood shavings, absorbent papers, coarse sawdust and beet pulp were also seen in use or reported as satisfactory. With all these materials, care must be exercised that they do not serve as a source of infection to the colony. Frequently provision is made to sterilize them before introduction into the colony. In prolonged experiments, such sterilization appears to have special merit.

The use of paper on rolls under mesh-floored cages is increasing. In colonies located in two of the large pharmaceutical houses, this procedure has worked very well when a heavily creosoted, non-sbsorbent paper

is used. The creosote appears to aid in decreasing odor. In one of these colonies, the paper was renewed every other day. Heavily waxed papers were also used satisfactorily for this purpose.

It is almost universal practice to provide bedding or nesting material in breeding cages. Most of the granular materials mentioned above for bottoms plus shredded paper were found in use in various colonies. In many breeding colonies the animals live directly on the bottoms material. This appears more practical in breeding cages where the animal is supplied with excess food. In experimental studies where inadequate amounts of food are provided, the hungry animal may eat bedding or bottoms material as well as feces, if available to him. The mesh-floored cage has an advantage in preventing this.

Infestation and Infection Control

Laboratory animals are subject to a number of infections and infestations. Proper design of the colony will permit operational procedures to be followed which can serve to control or even eliminate such complications.

Parasites and bacterial, viral or protozoan invaders may enter with personnel, feed, water, bedding, air, wild rats or mice, vermin, or on the bodies of new animals introduced into the colony. Some colonies have brought all of these factors under control to an extent that one might say the colonies are infection-free.

Infection-Free Operation

The term "infection-free" means that the animal is entirely normal with the natural bacteria and enzyme systems present so that its response to dietaries and outside organisms is that of any undiseased animal. Two rat colonies operated infection-free were seen in our visits to animal laboratories.

Infection-free should not be confused with "germ-free" operation as developed at the Lobund Laboratories at Notre Dame.* In germ-free operation the animals are not normal since the natural bacteria and enzyme systems are not present. Germ-free animals are not able to handle some dietary components and because of the absence of normal bacteria and enzymes they are unduly sensitive to such factors introduced from outside sources.

Infection-free newborn animals with which to start an infection-free colony are obtained by Caesarean section. Animals born in this way have been shown to be germ-free* (asceptic) and when placed in infection-free quarters can be maintained infection and infestation-free by following certain rigid precautions.

Ideally, all materials entering the colony are heat-treated or cleaned before entry is permitted and no materials are brought in not essential to the operation of the colony. Food is heat-treated to destroy infectious material. Grain components of diet are prone to be sources of trouble. Special mineral and vitamin supplements are obtained from sources which guarantee them to be free from undesired organisms. Bedding for breeding cages and litter materials are also heat sterilized. Dirty cages which have been cleaned outside of the colony are heat sterilized before being returned to the colony.

All personnel entering the colony are required to strip and shower, using soap freely. Clothing worn in the colony is kept in the colony. Only such personnel as are actually required for animal care and observation are allowed in the colony room. Particular care must be taken to insure that individuals who may have handled infected animals are not allowed into

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*Lobund Report #1. University of Notre Dame, November, 1946.

the colony before thorough cleaning of body and clothing has been carried out.

Conditioned air used in heating the colony is filtered through multiple filters to remove infection-carrying dust.

The colony room itself is sealed up tight. Floor drains, windows, and all unnecessary openings are eliminated. The room is operated under a slight positive air pressure so that any air leakage is out. By these means complete control is exercised over the materials entering the colony.

Animals raised in other colonies are not introduced into such a colony as they may be infected or pick up infection in transit from one colony to another unless unusual precautions are taken.

The importance of such measures depends on the probable duration of the experiment, the importance of the individual animal, and the magnitude of effects being studied. Such procedures give maximum assurance that valuable animals will not be lost. This is of special importance in long-term experiments where each animal represents many man-hours of work should duplication be necessary.

Workers using these methods find the animal response to nutritional factors more precise, since the unpredictable variations due to infection have been eliminated. This is especially important where the magnitude of effects being studied is small and might easily be masked by organic or infectious disease.

The operation of a "quarantined" colony requires additional operational expense. In long-term experiments, fewer animals can be used due to the greater expectation of survival of significant numbers

of animals at the end of the experiment. Such operation constitutes insurance against epidemic loss of a colony (and accrued man-hour expenses). These facts appear to justify the additional expense of operating a quarantined colony, especially where studies covering a long period are involved.

General Infection Control

Only two colonies visited practiced all the rigid precautions outlined. Many, however, have found it advantageous to practice certain of the precautions in their effort to reduce infection and infestation in their colonies. A number have adopted sterilized bedding and litter, feeling strongly that they constitute a serious source of infection and infestation in their colonies.

Many of the larger colonies employed air-conditioned ventilating systems in which the conditioned air delivered to the laboratories had passed through filters to remove dust. This practice appears generally feasible for all colonies so heated.

It was felt by all colony operators visited that strenuous effort should be made to keep wild mice and rats out of the colony building and that vermin control should be practiced. Few colonies had been as successful in this matter as they might wish.

Most colonies used insecticides to control flies, roaches, and similar pests. In a number, weekly spraying with DDT serosol was practiced. Others sprinkled DDT powder around the perimeter of the floor of the colony. At least one colony employed paints on walls, ceilings, exposed piping, and floors that contained DDT. The floor paint was an enamel type paint and scuffing away of the surface was depended upon to expose fresh DDT over a period of time.

A number of colonies have found it desirable to have insect control work done by an outside organization specializing in such work. Responsibility is thus clearly established and no longer is just another duty of the colony caretaker.

The heat processing of diet is perhaps the most difficult operation of the quarantined colony. It demands that the colony prepare its own diet which increased expense. However, present methods of shipping diets and diet components under conditions where wild rodents have access to them cannot be accepted where the introduction of infection must be scrupulously prevented.

The inconvenience of restricting the number of personnel entering the colony and further of requiring those who do enter to disrobe, shower, and wear special clothing in the colony is quite real. However,we were impressed by the number of colony operators who were well aware of the danger of personnel entering their colony who had been exposed to other rats, either wild or in other experimental colonies. Many operators felt strongly that all personnel not actually required for colony care or observation should be kept out of the colony. Provision of sealed windows for observation of the colony by other personnel or visitors was felt by many operators to be extremely desirable.

Waste Disposal

During normal operation of an animal colony, one is faced with disposal of bottoms material, dead and diseased animals. Most of the colonies visited disposed of such wastes in incinerators. In general these units were provided for burning of not only these wastes but any other organic wastes from the laboratory with which the colony is associated.

At a few colonies visited, the bottoms material was dumped in a pile on the property and made available to the staff as home garden fertilizer. One large breeder reported general fertilizer use of such materials with good results.

Most laboratories employed small gassing chambers for killing of extra young.

In those colonies doing virus work, all sacrificed animals and their bedding were steam sterilized in an autoclave before disposal by the procedures outlined above.

ALBINO RAT

Strains

Several strains of albino rats are widely used in the United States, especially for assay and nutrition work. Among these are the Wistar, Sprague-Dawley, Pybald, and the Bussey. Many users of rats have developed strains of their own, starting with healthy stocks of one of the strains mentioned above. Each strain of rat will vary in size at a given age and response to dietary and other influences. It is questionable whether these variations are sufficiently great to warrant special attention except in the most specialized experiments.

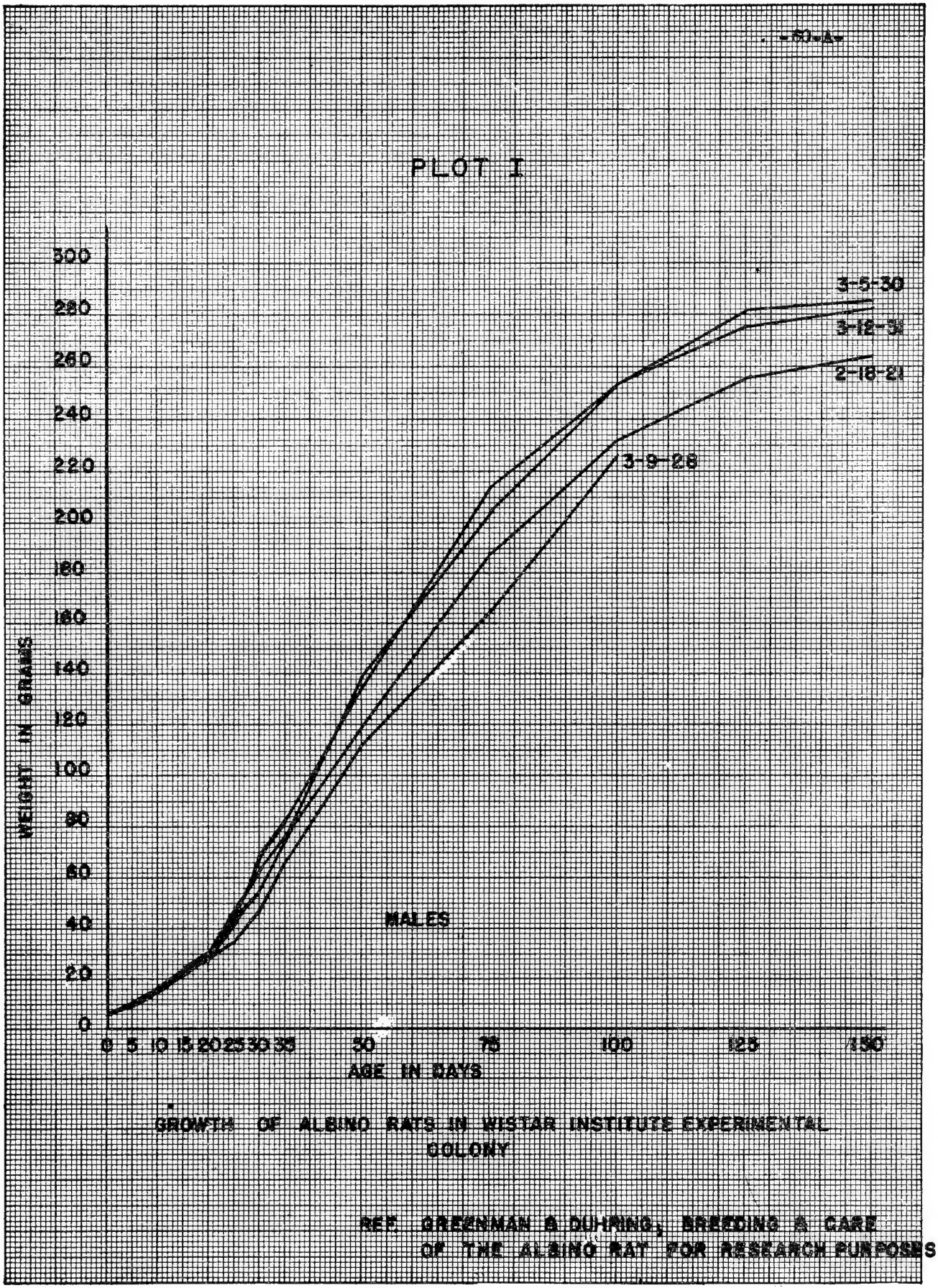
Size

Plot I gives data showing the typical growth pattern of male rats in the Wistar Institute Experimental Colony strain over a period of four years. The workers submitting this data felt that variations from year to year were in part due to changes in hygienic conditions and diet.

Dimensional data are given in Table I which presents approximate body measurements of Wistar albino rats at four stages of growth. These data permit calculation of the approximate area subtended and volume occupied by a rat. These dimensions are of importance in designing cages and emphasize the importance of knowing to what age the rat is to be maintained.

Feed and Water

Food requirements (i.e. the quantity required) of the rat are primarily a function of the animals' age. When rats are weaned at 28 days, they will consume about six grams a day of a mixed feed such as Purina chow. This amount will gradually increase to a maximum of about 15 grams per day at 90 days of age. Water requirements change



GROWTH OF ALBINO RATS IN WISTAR INSTITUTE EXPERIMENTAL COLONY

REF. GREENMAN & DUHRING, BREEDING & CARE OF THE ALBINO RAT FOR RESEARCH PURPOSES

TABLE I

APPROXIMATE BODY MEASUREMENTS OF WISTAR STRAIN ALBINO RATS

Age		Male	Female	Body Length	Tail Length	Height Middle of Back Standing	Height Middle of Back Lying	Body Width Standing	Body Width Lying	Max. Area sq.in.	Max. Disp. Vol. cu.in.
5 days	M	x		1½"	½"	3/4"	½"	½"	3/4"	1.12	.56
	F		x	1½"	½"	3/4"	½"	½"	3/4"	1.12	.56
30 "	M	x		3"	2½"	2½"	2"	2"	2½"	7.50	15.00
	F		x	2 3/4"	2¼"	2½"	2"	2"	2½"	6.98	13.80
100 "	M	x		5"	5"	3½"	2½"	2½"	3"	15.00	43.8
	F		x	4½"	4½"	3¼"	2¼"	2½"	3"	13.50	36.50
1 yr. or more	M	x		6½"	6½"	4"	3"	3½"	4"	36.00	91.1
	F		x	6"	6"	3 3/4"	3"	3"	3 3/4"	22.50	67.50

but little after weaning, and are about 15-20 cc per day per rat. The lactating mother carrying a litter of eight young will consume about 30% more water.

Sanitation

The rat is normally a clean animal and does not like to live in an area contaminated with its own excreta. It will usually urinate and defecate in the same place in its confined area so that the rest of the cage will stay relatively clean. The output of urine and feces will vary with age. At 30 days about 5 cc of urine and 10 grams of feces will be excreted per day. This will increase to about 10 cc of urine and 20 grams of feces per day at 100 days. The 100-day output will continue throughout the life of the animal.

Infection

The albino rat is subject to a variety of infections. These can usually be traced to a limited number of causes and factors. Sudden changes in temperature and humidity will frequently result in respiratory infections. Abnormally low or high temperatures maintained in the colony for prolonged periods may render the animal more susceptible to infection. Diseases of the rat may reach the colony-animal by way of infected litter, food, or by vermin. While many handlers of rats feel that humans transmit their respiratory infections to rats, operators of many colonies which are almost infection-free do not concur in this viewpoint. They choose to look upon the human only as a vector for rat infections which are for the most part not contagious to man.

Optimum Size of Colony Room

The floor area in the rat colony rooms at some of the colonies visited is given in Table II below. Cage space allowed per rat, aisle size, and

cage rack size varies from colony to colony which of necessity affects the data on colony room sizes.

The space figures in the data shown in Table II do not in general include space required for cage cleaning, feed preparation, or manipulation of the animals in the course of procedures primarily pertinent to the experiment. The space indicated is used only for housing animals

TABLE II

COLONY ROOM SIZE FOR ALBINO RATS

Rats per Room	Room Area Sq.Ft.	Sq.Ft. per Rat
1100-1200	648	.540
850	one room	
750	one room	
4000	2500	.625
800+	350	.438
10,000	4000	.400
300	270	.900
7000	1600	.229
5000	1800	.360

and for routine visual inspection while in the cages. Adequate aisles must be provided for removal of cage racks for cleaning and rolling in of castered tables carrying food and water supplies. For the basis of design, it appears reasonable to estimate that there will be required 0.4-0.5 sq. ft. of colony room area per rat.

Most operators questioned believe 1000 rats is an optimum number to be housed in any one room. This is based in part on labor requirements for the care discussed in a subsequent section. Segregation of the animals in small groups aids in preventing the spread of epidemic disease in the colony. The experience of operators of carefully quarantined colonies has shown that many more rats can be housed safely in one room without fear of epidemic problems when certain operational precautions are observed.

Lighting

The lighting of the rat colony was found to be a very controversial subject. Most colony rooms seen had external windows which made for variable lighter and darker periods of illumination during each 24 hours. Many colony operators practice a uniform cycle of light and darkness in the colony. It was particularly pointed out that the time and periods of breeding, exercising, and feeding are more regular under conditions of controlled and alternate periods of light and darkness which eliminates a seasonal variable from an experiment when the periods are of equal length throughout the year.

Operators of several colonies in which long-term studies of individual rats are carried out stated that they maintain uniform lighting 24 hours a day in the colony and could see no detrimental effects of any nature on the rats. It is reasonable to assume that the best results can be obtained in an experimental study if lighting conditions are reproduced every 24 hours.

Heating

Temperatures used for rat colonies range from 70-80°F with the range of 74-78°F covering most of the colonies seen. It was generally agreed that breeding rooms and colonies should be operated at temperatures nearer 80°F than 70°F. Relative humidities from 35-70% were reported in use but most colonies operate at approximately 50% R.H.

In considering summer cooling, one may estimate from the data of Benedict et al. (Journal of Nutrition Vol. 1, pp. 343-398, 1928) that the caloric output of 60-70 adult rats is approximately equivalent to that of one human, i.e., 550 BTU per 24 hours. Other heat loads in

the colony room will be the same as encountered in normal air conditioning problems. It can be calculated that the evaporation load imposed on the air conditioning system by the urine and feces excreted by the rats will not materially affect the air conditioning system. When 1000 rats are housed in a room having 400 sq. ft. of floor area and a ceiling 10 feet high, and air is introduced at the rate of six changes per hour at 78°F and 50% R.H., an increase in relative humidity of only 2-3% will occur due to evaporation of about 0.92 pounds of urine produced by the 1000 rats per hour.

Cages

Size

Cage size should be selected on the basis of the maximum size the rat will reach while in the cage and how many rats will be caged together.

Table III presents a summary of cage sizes in use in several colonies for housing various numbers of adult rats. In the last two columns of the table the data are calculated to an approximate per rat basis.

Wide variation is to be noted in these data. It was observed in visiting colonies that the trend is toward use of cages providing lowered cubage per rat than formerly.

While the data do not permit a positive conclusion as to the most desirable cage sizes, Table IV presents what may be reasonable minimum cage sizes for single and multiple caging of adult albino rats.

The size of the cage desirable for housing of smaller rats can be based on a proportionality to the rats' sizes. Considering that

the suggested cage sizes in Table III are to be used for a rat subtending about 26 sq. in. of cage floor area, one can estimate cage size from the data given in Table I for rats of other ages.

TABLE III

Cage Dimensions inches L	W	H	Cage Floor Area sq.in.	Cage Vol. cu.in.	No. of Adult Rats	Cage Floor Area per Rat sq.in.	Cage Cubage per Rat cu. in.
12	4	6	48	288	1	48	288
8	8		64		1	64	
9" diam.			81		1	81	
10	10	8	100	800	1	100	800
10	10	9	100	900	1	100	900
10	6	6	60	360	1	60	360
10" diam.			100		1	100	
10	7	7	70	490	1	70	490
12.5	8	10	100	1000	1	100	1000
12.5	7.5	7.5	78.7	590	2	39	295
8.25	8.25	4.25	68	289	2	34	145
14	7	7	98	685	2	49	343
14	7	7	98	686	2	49	343
14	14	7	196	1372	4	49	343
14	10	10	140	1400	5	28	280
20	15	10	300	3000	5	60	600
30	20		600		5	120	
20	10	10	200	2000	6	333	333
21	12	6	252	1512	7	36	216
24	24	11	576	6340	8	72	792
34	16	11.5	544	6260	10	54.4	626
60	18	10	1080	10,800	50	21.6	216

TABLE IV

No. of Rats	Length	Width	Height	Cage Floor Area per Rat, sq.in.	Cage Cubage per Rat, cu.in.
	inches				
1	12-14	6-5	6	70	400
2	10-14	10-7	6	50	300
4	16-14	10-14	6	40	240
More than 4	Proportional	10-14	6	40	240

Thus for caging a rat who will not be permitted to reach an age of over 100 days,

$$\frac{15}{26} \times 70 = 40.4 \text{ sq. in. floor area}$$

should be satisfactory.

A cage height of six inches is probably a desirable minimum, regardless of the age of rats.

The most popular rat cage is the drawer type, essentially a rectangular open top box. Cages of this type are supplied by several manufacturers. In some cases, the box is constructed entirely of wire mesh while in others only the front and bottoms are of mesh with the other three sides of sheet metal. The cages are suspended by slides along their top edge running in angle guides on the under sides of the solid shelves of the racks holding the cages.

The general usefulness of this design has been further enhanced by building cages in sizes which are twice and three times the width of the base cage. These larger cages fit the same angle guides as used on the narrower cages, making it readily possible to use the same supporting racks for three different sizes of cages.

Access to the cage for removal of the animal is through the open top, when pulled out from under the shelf to which fastened. Usually, jar feeders placed in the cages and water bottles mounted on the outside of the cage are used for feeding and watering in this type of cage.

Great variation in opinion is found as to whether sides of rat cages should be of mesh of sheet metal. Some colony operators stress the desirability of rats being able to see each other. Others state that mesh sides permit the rats to bite the tails of animals in adjoining cages, making them difficult to handle. Cages without open sides are considered of value by many users as a means of reducing drafts on the animals. It appears to us that all mesh or mesh-floored and solid-wall

cages can be used successfully if other factors in the colony design are adequate. Animals maintained on an inadequate diet may require special cage design to prevent cannibalism.

When the amount of dietary must be measured, many workers use a feed cup provided with an outer annular container into which material spilled from the main holder will fall. Other workers prefer a feeder having a baffle with a hole in it through which the rat can reach the food compartment. The hole in the baffle is made small enough to prevent withdrawal of the rat's head while the mouth is stuffed with food. When eating granular or powdered food, the rat normally makes use of his feet for getting the food into his mouth and food spilled while feeding will fall back into the feed holder.

Colony Labor Requirements

It was found difficult to obtain satisfactory estimates of the labor requirements in a rat colony. The data given in Table V suggest figures which appear useful in planning colony personnel requisitions.

The data indicate that one adult male can usually assume the full care of 400-450 adult rats including feeding, watering, changing bottoms, diet preparation, and cage cleaning. If the last two items are eliminated, one person can probably service 1000-2000 rats.

Labor requirements for cage washing have been discussed previously under the general section on cage cleaning.

Rat Breeding Procedure and Yield

At most rat colonies some breeding is carried out. At many, breeding within the colony supplies the greater part of the rat requirements for the institution served.

TABLE V

LABOR REQUIREMENTS OF RAT COLONY

No. of Personnel	No. of Rats	Type of Care	Rats per Person
1	3000	Feed, water, change bottoms	3000
1	600 adults 1000 young per month	All care but cage washing	Equivalent to about 1200
3	4500	Entire care of breeding colony	1500
2	750	" " " "	375
1	450	" " " "	450
1	1500	Feed, water, change bottoms	1500
3 1/2	4000	Entire except cage washing	1200
4	10,000		2500
5	2000	Entire	400
4	2000	Entire	500
7-8	7000	Entire	850
1	400	Entire, radioactivity study	400
3	5000		1666
1	1000	Entire except cage washing	200-250

While both monogamous and polygamous breeding is known, most colonies use a plan of polygamous breeding. Litters are in most colonies culled to 5-7 young per adult female. In most instances weaning is done at about 21 days. Females are rested for periods of two weeks to three months before being mated again. Females are bred four times in most of the colonies visited although in a few they are used five or six times before being discarded. Males in general are used for a year and then discarded.

Table VI shows the yield of young in some of the colonies visited. Marked variation is to be noted. Many of the breeding colonies prefer to accept lower yields resulting from procedures which require minimal labor.

The data suggest that a production rate of two young per adult female per month is reasonable. In polygamous breeding, with frequent

TABLE VI

YIELD OF RAT BREEDING COLONIES

No. of Females	No. of Males	Monthly Yield of Young	Young per Female	Young per Adult
590	143	1820	3.1	2.5
353	48	1600	4.5	4.0
600 total		1000		1.7
120	30	600 (4 wks.)	5.0	4.0
350	?	800-1000	2.6	?
600	?	1000	1.7	?
1	1	9	9	4.5

inspection and removal of pregnant rats from the breeding cages and replacement with rested or virgin females, the yield can be quickly increased to 4-5 young per female per month. The highest yields were reported by a colony which produced a litter every 25 days when continuous monogamous breeding was employed. Under this procedure the female is allowed to become pregnant again as soon as possible after delivering a litter.

It may be calculated (Table VI) that methods used by the second colony in the table required 20,800 sq. in. of cage floor area to produce 1600 rats per month while those of the last colony in the table required 17,800 (based on cage sizes noted in section on cages above). The methods of the second colony require 400 adult rats while those of the last colony require 356 rats. It seems probable that the less frequent mating of the second colony will make for a more vigorous stock although the excellent quality of the stock produced by the last colony is well known.

MICE

Colony Room Size

When caging adult mice, 8-10 animals per 11" x 7" x 7" cage, 1000-1500 mice can be housed in a room 12' x 16' x 11' high. The higher figure tends to crowd the room. These figures allow only for caging plus aisles to permit changing cages. All diet preparation, cage washing and detailed examination of the animal is done elsewhere.

Cage Size

Table VII gives the dimensions of cages used to house various numbers of mice by various colony operators.

TABLE VII

MOUSE CAGE SIZES

Length	Width	Height	No. of Mice	Cage Area per Mouse sq.in.	Cage Cubage per Mouse cu.in.
	inches				
12	12	6	3	48	288
11	5	6	5	11	66
5	7	5	5	7	35
8.25	8	4.25	5	13.2	56.2
12	7	6	7	9.3	72
11	7	6	8	9.6	57.7
11	8	7	10	8.8	61.6
10.5	7.5	7.5	20	3.94	24.6
10	14	10	25	5.6	56.0
24	16	3	25	15.3	46.0
12	18	6	25	8.6	51.8
22	20.25	9.5	100	4.45	42.3
31	17	15	150	3.51	52.0

Marked variation in actual practice is seen. Table VIII presents suggested cage sizes which appear adequate in space allowances for various numbers of mice.

TABLE VIII

SUGGESTED ADEQUATE SIZES OF MOUSE CAGES

Length	Width	Height	No. of Mice	Cage Floor Area per Mouse, sq.in.	Cage Cubage per Mouse, cu.in.
	inches				
7	6	6	5	8.3	50.5
10	7	6	10	7.0	42.0
15	10	6	25	6.0	36
30	15	6	100	4.5	27

Cage Construction

While many mouse colonies use wire cages as for rats, a number were visited in which glass, metal, wood, and plastic cages were employed. Battery jars, gallon and two-gallon ointment jars were seen in use. In general, screen covers were placed over the opening of the jars with water bottles supported on the covers.

Clear plastic cages were seen in a few colonies. These were in the shape of rectangular boxes with a flared top edges serving as supporting slides. Similar cages were seen made out of stainless steel. Mice appear to do well with a minimum of provision for air changes within the cage, making cages with solid sides permissible. Such solid sides and bottoms cages have the additional advantage of confining the animal, its food and excreta in a definite space. This has been especially useful in virus work and would appear of value for radioactive studies.

Labor Requirements

Since multiple caging is usual with mice, colony labor requirements are less per animal than for rats. In the colonies visited, the average labor requirement found was one man per 3000 mice or 500 cages.

Breeding

Breeding of mice follows usually the polygamous procedures discussed for rats, two to twelve females are mated with one male. Litters are culled to 5-8 and females are allowed to breed three or four times.

Dietary

Adult mice will consume about 5 grams a day of a pelleted diet such as Purina Laboratory Chow. Hopper feeders are widely used.

GUINEA PIGS

General

Animal quarters of the general type described are well suited to housing guinea pigs. A slightly lower temperature can probably be used, but humidity should still be in the range of 50%. The data below were collected during visits to working colonies. Few of these colonies used many guinea pigs and in general kept them in rabbit or rat cages.

Cage

TABLE IX

CAGES FOR GUINEA PIGS

Width	Length	Height	No. of Pigs	Cage Floor Area per Pig	Cage Cubage per Pig
	inches				
7	14	7	1	98	686
7	17	10	2	59.5	595
12	18	20	4	54	1080
16	20	12	5	64	767
24	36	6	6	144	1728
17	31	15	25	21	375

Based on the colonies visited, guinea pigs are most commonly housed directly on litter. Screen bottom cages, however, are also successfully used. Regardless of the bottoms procedure, care should be exercised to preclude dampness. Bottoms should be changed frequently enough to assure such dryness.

Dietary

Guinea pigs require 2-5 milligrams per day of vitamin C for good health. These levels will be somewhat higher for females during pregnancy. Practice is to supply such vitamin C in the form of fresh greens or tomatoes. Daily consumption of a solid dry complete ration is 20-30 grams per adult pig. Feeding usually is by means of a feed crock similar to that used for rabbits. Water bottles or a water dish can be employed.

RABBITS

General

The housing of rabbits in the laboratory requires the same basic type of quarters as already described. In general, quarters should be kept cooler than for rats and mice with temperatures of 65-75°F being recommended.

Cages

Most colonies inspected used wire mesh cages with wire mesh floors so that fecal matter may drop into pans below. The following cage sizes were seen in use.

TABLE X

SIZES OF RABBIT CAGES

Length	Width	Height	No. of Rabbits	Cage Floor Area per Rabbit	Cage Cubage per Rabbit
	inches				
18	12	11	1	216	2375
22	10	13.5	1	220	2970
22	20	15	1	440	6400
9	17	11	1	153	1683
18	12	14	1	216	3020
16	12	14	1	192	2240
20	16	12	1	320	3840
17	21	12	2	179	3150
36	27	42	3	324	13600
31	17	15	3	176	2640

The breed of rabbit used will be a decided factor in selecting a cage since the large breeds weigh 14-17 pounds as contrasted with 3-6 pounds for the small breeds.

Colony Labor Requirements

Opinions as to labor requirements to care for rabbits varied from 150-350 rabbits per man.

Colony Room Size

The number of rabbits one can house in a given room is obviously much less than the number of rats. In one colony seen, where crowding was not excessive, 130 single rabbit cages 20" x 16" x 12" were maintained in a room 15' x 20' x 12' high.

Dietary

Dietary requirements of rabbits are of the order of 100-150 grams per day of a complete ration such as Purina Rabbit Chow. The daily requirements will increase with pregnant females reaching as high as 500-1000 grams per day six weeks after parturition. Many colony operators recommend keeping a salt spool in all rabbit cages.

DOGS

Cages

Cage sizes seen for dogs were as follows.

TABLE XI

CAGE SIZES FOR DOGS

Length	Width	Height	No. of Dogs	Cage Area per Dog, sq.in.	Cage Cubage per Dog, cu.in.
	inches				
36	27	42	1	972	40,800
36	36	60	1	1296	77,800
24	26	24	1	865	20,750

While many dog quarters seen consisted of permanent concrete kennels, a number of institutions in setting up new facilities have used the large sizes of wire mesh or expanded metal cages. Provision is frequently made for collecting fecal matter in drains which can be flushed several times a day.

The necessity of exercising experimental dogs is very controversial. Based on the success of several large users of dogs, it appears that runs are not necessary. While dogs appear to enjoy runs, frequently, their exercising becomes a variable which is difficult to integrate into the factors bearing on the results of the experiment.

Quarantine Facilities

Very few colonies attempt to raise their own dogs but depend upon dealers. This necessitates space in the colony area where dogs brought in from the outside may be quarantined to check them for infection, vermin, and give them injections such as distemper serums. Usually such a quarantine room will contain tanks for washing the dogs and for dipping animals in disinfectant solutions. In most colonies such a quarantine room also served to check the health of other species of animals purchased on the outside for use in the colony.

HOUSING AND HANDLING ANIMALS IN THE PRESENCE OF RADIOACTIVITY

General

Very few of the animal colonies visited in our survey were carrying out experiments where animals were fed, or exposed to, radioactive isotopes. In those few laboratories where radioactive isotopes were used, the experiments were chiefly tracer studies involving low radiation intensities. All work seen had been done with rats. In the following paragraphs the methods used are outlined.

Caging

In all the laboratories seen, including one which had worked at radiation intensities of 8 millicuries per adult rat, the rats were housed in conventional wire cages. Cages containing "hot" animals were usually marked or tagged some distinguishing color, generally red. Practice has been to hold used cages in storage until sufficient radiation decay had taken place to permit safe handling. A few colonies are considering the use of disposable cages. A plastic cage has been used by one laboratory for some time on non-radioactive work and found suitable for rats and mice. Such cages would be burnable for disposal if necessary.

Bottoms

Most colonies were employing their regular bottoms procedure. One seen used plain pans with no absorbent material to collect excreta, feeling that the reduced volume of radioactive material was desirable. Experience has shown that most of the excreted radioactive materials appear in the feces, usually in the ratio of 90% in the feces to 10% in the urine. Thus in metabolism work, feces and urine separation must be done very carefully with special care given to preventing the washing of feces with urine.

While many workers are employing conventional urine and feces separators, one laboratory visited had developed a positive separation procedure for use on male rats which had given sufficiently improved results to justify its use.

Feeding and Watering

No special facilities were seen for feeding animals radioactive diets or for preparing such diets.

Heating and Ventilation

Among the organizations now using radioactive isotopes with rats, care was taken to filter exhaust air from most of the colony rooms. Exhaust air was vented at as high a point as possible to allow for dissipation by dilution. One group was proposing to install venturie jets to discharge the air at high velocity and thus carry it well up into the air. One firm setting up an animal colony for radioactivity studies is designing their air conditioning system for 20-25 changes of air per hour and to maintain 70-72°F and 40-60% R.H.

Waste Disposal

Most laboratories doing or proposing to do radioactive isotope animal work contemplate disposing of rapidly decaying radioactive wastes by burial, and returning long-life materials to the A.E.C. One large laboratory visited proposed to dispose of wastes by dumping in a large river. Increase in radioactivity level in the river will be followed by measurements on downstream bars and clams.

Liquid wastes will be concentrated in one laboratory by evaporization or ion exchange. Another laboratory proposes the use of settling tanks for some of their hot wastes. All groups are taking great precautions

to prevent wastes from getting into the normal waste systems of the area.

Colony Room Constructional Details

The design of rat colony rooms currently used or planned for radioactive work follows the pattern below. Where possible, walls should be smooth surfaced with as few joints as possible. Poured concrete, plywood, stainless steel sheet were variously recommended. Many workers hope to apply strippable films to walls and working surfaces. Tygon films strippable by wetting with acetone were reported in use by one laboratory. Tile floors were recommended since sections of them could be readily replaced.

Layouts should involve as few dust catching items as possible. Concealed flush lighting, service piping concealed in duct work, radiant heating, are all features mentioned. The elimination of floor drains was stressed as such drains encourage the indiscriminate disposal of radioactive wastes without proper attention by qualified personnel. Several groups designing radioactive laboratory and colony space are stressing having all fixtures such as benches, sinks, hoods, so constructed as to be removable and easily disassembled to permit complete decontamination. Sink drains desirably are run out of the laboratory above the floor so as to be readily accessible.

Counting

It was generally agreed by all groups contacted that all counting work should be done in a separate room rather than in the colony room. Close proximity to the colony room, however, was stressed.

APPENDIX B

ANIMAL COLONIES VISITED

The animal colonies operated by the following organizations were visited during the course of our studies. Arthur D. Little, Inc., wishes to express their appreciation and that of the Brookhaven National Laboratory for the cordial reception extended by each of these organizations and their generous allotment of time and personnel to show and explain their animal housing and handling techniques.

Abbott Laboratories, North Chicago, Illinois

AEC Animal Laboratories, University of Rochester, Rochester, New York

Army Chemical Center, Toxicological Laboratory, Medical Division, Edgewood, Maryland

Banting Institute, Toronto, Canada

Chalk River Laboratory, Chalk River, Ontario, Canada

Columbia University, College of Physicians and Surgeons, New York, New York

Cornell University, Division of Animal Husbandry, Department of Nutrition, Ithaca, New York

Distillation Products, Inc., Rochester, New York

E. I. Dupont de Nemours Company, Haskell Laboratory, Wilmington, Delaware

E. I. Dupont de Nemours Company, New Brunswick, New Jersey

Eli Lilly and Company, Indianapolis, Indiana

Harvard University, Biology Department, Cambridge, Massachusetts

Hoffman-LaRoche, Inc., Nutley, New Jersey

Lederle Laboratories, Division of American Cyanamid, Pearl River, New York

Lobund Laboratories, Notre Dame University, Notre Dame, Indiana

Massachusetts Institute of Technology, Biology Department, Cambridge, Massachusetts

McGill University, Department of Anatomy, Medical School, Montreal, Canada

Mead Johnson and Company, Evansville, Indiana

Merck Institute, Rahway, New Jersey

National Cancer Institute, Bethesda, Maryland

National Institute of Health, Bethesda, Maryland

Navy Medical Research Institute, Bethesda, Maryland

Parke-Davis and Company, Detroit, Michigan

Phipps Institute, Psychobiological Laboratory, Johns Hopkins Hospital, Baltimore, Maryland

Rockefeller Institute, Princeton, New Jersey

Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine

Sharp and Dohme, Glenolden, Pennsylvania

Sloan Kettering Cancer Institute, New York, New York

Sprague-Dawley, Inc., Madison, Wisconsin

Squibb Institute, New Brunswick, New Jersey

Sterling-Winthrop Research Institute, Rensselaer, New York

Swift and Company, Central Animal Headquarters, Amogo, Illinois

University of Chicago, Central Animal Quarters, Chicago, Illinois

University of Cincinnati, Cincinnati, Ohio

University of Toronto, Department of Biochemistry, Toronto, Canada

Upjohn Company, Kalamazoo, Michigan

U. S. Food and Drug Administration, Division of Pharmacology, Washington, D.C.

Wisconsin Alumni Research Foundation, Madison, Wisconsin

Wistar Institute, Philadelphia, Pennsylvania

APPENDIX C

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